51 S.W.

MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE

GEOLOGY OF THE NEIGHBOURHOOD OF CAMBRIDGE;

(EXPLANATION OF QUARTER-SHEET 51 S.W., WITH PART OF 51 N.W.)

BY

W. H. PENNING, F.G.S.,

AND

A. J. JUKES-BROWNE, B.A., F.G.S.

WITH A PALÆONTOLOGICAL APPENDIX,

BY

R. ETHERIDGE, F.R.S., L. & E., Pres.G.S.

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NOTICE.

In the following Memoir a district is described which comprises an area of about 300 square miles. The information which it contains is so minute in all details in relation to practical, theoretical, and Palæontological Geology, that it cannot fail to be of use to all persons interested in the Geology of Cambridgeshire.

ANDREW C. RAMSAY,
Director-General.

24th May 1881.

N 309. Wt. 6093.

NOTICE

THE area described in this Memoir was surveyed by MESSRS. PENNING AND JUKES-BROWNE, under the superintendence of MR. WHITAKER.

Each of the authors has described the special district which he surveyed, and the combined results have been arranged in concert with MR. WHITAKER, who has edited the whole, and contributed the valuable Bibliographical Appendix, with some aid from MR. DALTON.

The Palæontological Appendix, by MR. ETHERIDGE, not only reviews the Palæontology of the different sub-divisions of the Chalk described in the Memoir, but also describes a number of new Cretaceous species.

This Memoir will be a valuable contribution to geological literature, the university town of Cambridge occupying the central part of the district; and it will not be without some economic value, as the area described includes a great part of that over which the so-called coprolites are worked at the bottom of the Chalk Marl.

Acknowledgments are due to engineers and well-sinkers for contributions of well-sections and borings.

H. W. BRISTOW,
Senior Director.

Geological Survey Office,
28, Jermyn Street, London, S.W.,
1st March 1881.

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THE

GEOLOGY OF THE NEIGHBOURHOOD OF CAMBRIDGE.

CHAPTER I.—INTRODUCTION.

PECULIARITIES OF THE DISTRICT.

THE area of which the geology is described in the following pages is small, but it is one which possesses peculiar interest from the light that its deposits have thrown upon those of more importance elsewhere. Owing to certain conditions in the physical geology of the district some deposits, such as the earlier Post-glacial gravels, have been here exceptionally preserved, in a manner which elucidates their method of formation. The multitude of sections in the Lower Chalk have afforded means of dividing that formation into distinct palæontological zones, a division which has not, until recently, been attempted in England.* And the extensive workings for phosphatic nodules in the so-called "Cambridge Greensand" have made clear the relations of that deposit to the Chalk Marl above, and the denuded Gault below. The extent covered by the Oxford and Kimeridge Clays is too small for much to be said upon those deposits, but the few exposures that occur foster the belief that similar divisions are possible (were the evidence collected with that view) as have been worked out in the Lower Chalk.

The district is geologically rich from the number of formations and periods that are represented, as may be seen from a glance at the map with its many colours, each representing a well-defined epoch. The Oxford and Kimeridge Clays, with doubtful Lower Calcareous Grit between them; the Lower Greensand and Gault, with an intervening unconformity; the great erosion which resulted in the formation of the "Cambridge Greensand," the Lower, Middle, and Upper Chalk, with the intermediate definite bands, may all be seen within a short distance of the town of Cambridge. And not these only, but examples of the later Glacial Drifts and the Post-glacial Drifts, so long regarded as presenting the type of chaotic confusion; which, now that they are worked out in detail, fall into a definite sequence; and each division may be studied within a radius of less than three miles.

The situation of Cambridge in other respects is equally interesting, the town standing just below the confluence of several streams, up to which point the river was navigable by the war vessels of early times. The sharp bend of the river and the higher ground on its left bank marked the site for a ford and station. The town is on the borders of the low-lying and formerly weird Fenland,

* By PROF. HÉBERT and DR. BARROIS.

but is still under the shadow, as it were, of the higher slopes and table lands of the great Chalk escarpment.

Rivers.

Our area lies almost entirely within the county of Cambridge, but it includes also small parts of Essex, Herts, Huntingdonshire, and Suffolk. It comprises the district which slopes from the escarpment of the Chalk on the south to the Fenland on the north, with the intermediate high ground that falls from the western side towards Cambridge. Hereabouts several streams converge, and form the River Cam or Granta, which after skirting the town on its west and north sides passes by Waterbeach to the Fens.

These streams are the *Rhee,* which springs from a bed in the lower part of the Chalk, and runs east from Wendy, closely following the base of that formation, until it receives a branch from Foulmire, when it turns in a north-east direction to its junction with the Cam, just south of Grantchester.

The *Granta* rises in the district south of our area,* passes through the Chalk escarpment by Chesterford to Shelford, where it is joined by the *Bourn* or *Lin,* that also rises in the Chalk, and thence it runs by Linton to the same point of convergence near Grantchester. Another stream, also called the *Bourn,* flows into the Cam at this point; it rises by a village of the same name, and passes by Kingston and Toft in a nearly east direction.

The *Full Brook* runs into the Cam just north of Cambridge; and there are in the north-east corner of the district other minor streams known as "Ditches" or "Loads" which run down to the Fenlands that border the river for the remainder of its course to the sea.

A short length of the Ouse passes through the area, running east from St. Ives to the Fens.

Physical Features.

The area treated of in this memoir is comparatively flat and at a low level, with the exception of the conspicuous Chalk escarpment, one of the Chalk outliers, and the ridge traversed by the high road running west from Cambridge to St. Neots. The first even rarely exceeds 500 feet, the last is under 200 feet in elevation. The outlier of Chalk, capped by Boulder Clay, rises from a plain of Gault on either side, and forms a long narrow ridge, which, although of no great height, presents an agreeable feature in the landscape.

The physical conformation of the ground is (with the exception of the Chalk slope) such as to induce dampness of soil and atmosphere; a characteristic which, as regards Cambridgeshire, has become proverbial. It is owing not to the rainfall, which in amount is small, about 23 inches a year, but to the low-lying area being surrounded by higher ground on all sides but one, by the preponderance of ground sloping to the north, and by the prevalence of clay soils.

There is another peculiarity in the meteorology of the northern part of the area at present unexplained, but which deserves investigation. This is the prevalence of certain conditions throughout a district, of which Chatteris is the centre, that give rise to hail-

* See explanation of Sheet 47.

storms, twofold in number and intensity to those which occur elsewhere. For insurance purposes the area thus affected is described as within a radius of 15 miles around Chatteris, and that this is roughly correct has doubtless been proved by experience; within the area one shilling per acre, and without it sixpence per acre, is paid as yearly premium for insurance against damage by hailstorms. Chatteris is situate not far from a central point in the southern bay of the Fens, from which a radius of 10 miles or so would nearly describe its boundary—from Gillsport, by Ely and St. Ives, to Peterborough—and from which the land rises in every direction, except towards the fens on the north. It may be that the cul-de-sac thus formed catches and retains an undue proportion of storms from the northward, causing them to eddy and discharge within the area so situated; certainly the phenomenon is due directly to this or some other peculiarity in physical conformation.

Another local phenomenon is the "drowning" of the fens, as the flooding of the tract is locally termed, to which they are subject from the bursting of banks and sluices. "The Great Drowned" of 1796, with its many incidents of suffering and ruin, is painfully reverted to even now by the few survivors old enough to remember that catastrophe.

Owing to the shrinking and gradual subsidence of the peat and alluvial deposits which have been laid dry for several years, the little hillocks or islands of clay protruding through attain a greater relative elevation. And it is a common notion with the labourers on the fens that "the clay rises," indeed it is not easy to convince them to the contrary.* In one case, for example, on Pidley Fen there was formerly a ditch to carry off water in a certain direction; the spot which 30 years ago was occupied by its lowest end where the water was discharged, now forms a small hillock of Oxford Clay some 4 or 5 feet above the surrounding peat.

Geological Formations.

The accompanying table shows the various formations and beds that occur in the district, the great gaps between them being marked by spaces :—

	Divisions shown on the map.
Recent	Alluvium, peat, &c.
Post-Glacial	River Gravel connected with the present streams.
	River Gravel of an older valley system.
	Gravel (? marine) at high levels.
Glacial	Boulder Clay.
	Gravel and loam in and below the Boulder Clay.
Cretaceous	Chalk: Upper.
	Chalk: Middle.
	Chalk: Lower.
	Gault.
	Lower Greensand.
Jurassic	Kimeridge Clay.
	Lower Calcareous Grit ?
	Oxford Clay.

* See also the Geology of the Fenland, by S. B. J. Skertchly, p. 154, *Geological Survey Memoir*. 1877.

The Jurassic series is represented in the N.W. corner of the area by the Oxford and Kimeridge Clays. These formations are of similar lithological character, and very few sections occur where fossil evidence can be collected, therefore the line of division is very indefinite.

The brickyard at Boxworth (p. 7) is probably, that at Knapwell (p. 9) is certainly, in Kimeridge Clay; the line is drawn below these two points following the form of the ground, and carried on to the narrow outcrop of calcareous grit which separates the two formations further W. (in Sheet 52 S.E.)

The grit is probably continuous with a small exposure of calcareous rock, a foot or more thick, with *Gryphæa dilatata,* just W. of Elsworth, a bed not to be confounded with the "Elsworth rock."

The Lower Greensand is but poorly represented in Cambridgeshire, and is, moreover, almost entirely concealed on the western sides of the area by a widespread sheet of Boulder Clay, a single small inlying exposure being found in the neighbourhood of Bourn. It emerges from beneath this covering of Drift near Lolworth, and thence it may be traced to the north-east as a narrow strip of reddish sandy ground between the dark heavy soils of the Jurassic and Cretaceous clays.

The Gault takes up a far greater area than the Neocomian sands, but the width of its outcrop varies greatly, and it does not form such a continuous plain as in the tract to the south-west, where it is less interrupted by outlying patches of chalk and drift.

The Chalk in its several divisions covers more than half the area included in Sheet 51, S.W., extending over most of the ground to the south-east of the long valley formed by the Rivers Rhee and Cam, with outliers of considerable size to the westward.

The whole country was at one time covered by Boulder Clay resting indiscriminately on the older rocks. It now occurs in mass only on the higher lands, and as outliers at low levels. Upon it and upon the denuded surface of the underlying beds are gravels of various ages; some dating from early Post-Glacial times, others being undoubted river deposits, but with no relation to existing watercourses, and, lastly, more recent gravels belonging to the existing valley systems.

[It may be well to note that the term "Post-Glacial" is here used in a local sense, for gravels newer than the Boulder Clay of the district, and without prejudging questions of classification of the Drift as a whole, or in other parts.—W.W.]

CHAPTER II.—JURASSIC SERIES.

OXFORD CLAY.

This formation occupies all the northern part of the district down to a line running about E.N.E. from Elsworth, by Boxworth and Long Stanton to Rampton, and is not covered to any extent by Glacial or Recent deposits.

The sections in which it can be examined are not numerous; but, wherever exposed, it is seen to consist of grey or bluish grey clay, laminated and fossiliferous. Sometimes the clay encloses small crystals of selenite, and in every case where any considerable thickness is shown, layers of limestone or of septaria occur. These layers are seldom more than a foot thick, but they are found at intervals of a few feet only, are fairly persistent over considerable distances, and indicate the general dip of the formation.

The thickness of the Oxford Clay in this part of England is not known, but from its dip, outcrop, and similar indications, we estimate it at about 700 feet. A bore-hole was made into the Oxford Clay at Bluntisham to a depth of 300 feet in the hope of finding water, and another at Conington to 256 feet, but no springs were met with, and the work was abandoned.

At Rumbold Farm, which stands on a knoll of Oxford Clay in High North (Somersham) Fen, there is said to be a hard whitish rock a few feet beneath the surface, this is probably lower down in the clay than the sandy bed at Fenton. At a higher horizon are the bands of limestone and septaria exposed in the cuttings on the St. Ives and March Railway, and on the new line from St. Ives to Sutton through Bluntisham and Earith. On the eastern slope of the cutting, a short distance south of Somersham station, three bands of septaria or of hard sandy limestone may be traced, although partly obscured by slips and overgrowth. The lines are about 6 feet apart, and appear nearly horizontal. About 6 feet above the highest bed there occurs a thin, but apparently very persistent, layer of hard, ferruginous purple-coloured clay, fossiliferous, and presenting some markings of a very peculiar character.

There are two large pits at Fenton, one mile N.W. of Pidley, one on each side of the road, from which the clay is dug for brickmaking; that on the west side shows 16 feet of bluish-grey clay, with crystals of selenite. The pit on the east side of the road, at a lower level than the other, 8 feet of grey clay, with a hard sandy bed 6 inches thick (in places only) in two or three layers.

The large cutting midway between St. Ives and Somersham is mainly through Boulder Clay, by which the ridge of high ground between those two places is capped, but in its lower part the Oxford Clay is exposed. Half a mile to the west of this cutting is a small spring, shown on the map as "The Spa," its water is slightly chalybeate, and is thrown out probably by a hard bed in the clay, which is not, however, seen in any section.

The long cutting, just S.W. of Bluntisham on the new line is almost entirely in Oxford Clay, which here encloses innumerable minute crystals of selenite. At its eastern end there is a bed of hard sandy limestone a foot thick, at about the level of the railway. At one point this bed is faulted, or rather bent down, for about two feet, the fractured ends of the stone are separated by a gap of 2 or 3 feet, but they incline towards each other and evidently have been continuous. A large lump of oyster rock projects from the slope of the cutting on the southern side, but it is not clear whether this is part of a bed in place, or a boulder from the Boulder Clay, which comes on a little nearer to the station.

The western end of the same cutting exposes two bands of rock in the clay, about 2 feet apart; the lower is rather more than 1 foot thick, hard, sandy, and calcareous; the upper is thinner, less hard, and less persistent. These bands are a little above the rail level, but whether either be continuous with the band

at the eastern end of the cutting was not apparent, several chains of the hill remaining to be cut through when these observations were taken (1877). The intervening portion, however, gave an opportunity of taking the dip of these beds, which was found to vary from 2° to 3° in a direction nearly north, that is, into the hill, as might be expected. This shows that the Oxford Clay, after rising to the north from beneath the Kimeridge Clay and the Neocomian beds, again sinks slightly in the same direction. The valley of the Ouse forms no exception to the general rule, but (hereabouts at least) has been cut deepest along an old anticlinal; and by the inward dip, above mentioned, the present ridge to the north has been preserved from denudation.

Another cutting on the new line, about three-quarters of a mile from the junction, shows two similar bands at about the same level, doubtless extensions of the same beds. There is a pit a few feet in depth close by the junction, but only clay is exposed.

The brickyard, half a mile north of St. Ives, is in fossiliferous blue clay; that half a mile further east is in the same clay, but exposes in places only (the section is overgrown and indefinite) a yellow hard band a few inches in thickness.

The large brickyard just west of St. Ives, near the edge of the alluvium, gives several small but good sections; the old high face on the north side of the pits, and in which all the beds might have been seen at one glance, being now overgrown. These sections occur in different parts of the field, the thickness of the clay between the harder beds exposed cannot, therefore, be easily estimated, but the general succession is as follows:—

1. Grey clay.
2. Fine purple calcareous sandstone.
3. Fine yellow " "
4. Blue clay.
5. Two fairly persistent beds of hard sandy limestone, each about 6 inches to a foot thick, and with 6 inches to a foot of clay between them.
6. Blue clay.
7. A bed or beds of hard sandy limestone (at the water-level.)

The limestones (5) are probably those referred to by Prof. Bonney, who says:—"Two well-marked seams of large flattened concretions, about a foot "apart, were exposed on the north side of the pit in 1874."* The beds (2 and 3) of purple and yellow coloured fine calcareous sandstones, may represent the Lower Calcareous Grit, which occurs between the Oxford and Kimeridge Clays at Papworth St. Everard, five or six miles south of St. Ives, or they may be merely, as Prof. Bonney has suggested, a "calcareous band which "we may call, for distinction, the St. Ives Rock."† We are, however, inclined to think that as the Oxford Clay rises into a slight anticlinal beneath the Ouse valley, this patch is at too low a level to represent the Calcareous Grit, and that it is much more likely to be on the horizon of the Elsworth Rock.

A much thicker rock than any of those already mentioned has been found at Elsworth, and described by Prof. Seeley as the "Elsworth Rock."‡ "A dark blue homogeneous limestone; . . . its thickness is very variable, ... commonly about three or four feet, though in some places not less than seven feet. On the top of it is a clay, of a reddish-brown, about five feet in thickness, and then an upper rock of 18 inches." This band of limestone is not shown in any existing section, except slight exposures by the brook-side, but its outcrop may be approximately traced, and is represented by a dotted line on the map (Sheet 51 S.W.)

The brickyard north of Boxworth is in bluish-grey clay (which may be

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* Cambridgeshire Geology, p. 10 (*note*).

† Ibid. p. 11.

‡ *Ann. Nat. Hist.* Ser. iii., vol. x., p. 98, (1862.) By some mistake Prof. Bonney has stated (Cambridgeshire Geology, p. 14) that this rock has been mapped by the Geological Survey as Calcareous Grit.

either Oxford or Kimeridge), with two thin layers of whitish sandy limestone, separated by a foot of clay, and very fossiliferous. There is said to be a layer of septaria, several feet below these limestone bands; the concretions seen in the pit contained *Ammonites biplex* in abundance.

This brickyard is described by Prof. Seeley, who mentions the occurrence of a rock here about a foot and a half thick. He says, "the workmen call it 'flint,' a name I have also found given in the surrounding district to the septarious concretions of the clays. It is dark blue, very hard, and divided into layers much as is the Elsworth Rock. The only specimen of it I saw was a slab from the upper part, about six inches in thickness, which consisted of two layers, an upper dark blue one with a few small shells scattered about in it, and a lower pale brown layer composed almost entirely of shells, chiefly univalves." He records the following fossils from this rock:—*Ammonites biplex*, *A. alternans ? Alaria bispinosa*, *Cerithium muricatum*, *Pecten lens*.

From the clay beneath he obtained *Ostrea deltoidea*, *Gryphæa dilatata*, and another oyster resembling *O. leviuscula*. We have also found *Exogyra nana ?*

The Oxford Clay, of bluish-grey colour, and enclosing small crystals of selenite, may be seen in a railway-cutting 1 mile N.W. of Long Stanton Station, in a brickyard north of the cutting, and in an old brick-pit north of Willingham.

List of Fossils from the Oxford Clay and the included Rocks, compiled from the Collections in the Woodwardian Museum, the Nomenclature revised by Mr. Etheridge; a few Additions have been made to the Second Column:—

——	St. Ives Brickyard.	St. Ives Rock.	Elsworth Rock.
Annuloida:			
Acrosalenia spinosa ? *Ag.*	×		
Cidaris	...	×	×
Collyrites bicordatus, *Leske*	...	×	
Pseudodiadema	...	×	
Holectypus depressus, *Wright*	...	×	
Millericrinus echinatus, *Schloth.*	...	...	×
Pentacrinus	×	...	×
Annulosa	×		
Glyphœa rostrata, *Phil.*	×		
„ scabrosa, *Phil.*	×		
Serpula tricarinata, *Sby.*	×		
„ vertebralis, *Sby.*	×		
Vermilia (Serpula), sulcata, *Sby.*	×		
Brachiopoda:			
Rhynchonella lævirostris, *McCoy*	×		
„ varians, *Schloth.*	×	×	
Terebratula impressa, *V. Buch.*	×		
„ insignis, *Schübler*	...	...	×
„ intermedia, *Sby.*	...	×	
„ obovata (var.), *Sby.*	...	...	×
Waldheimia bucculenta, *Sby.*	...	...	×
Lamellibranchiata:			
Arca æmula, *Phil.*	...	...	×
„ subtetragona, *Morris*	×		
„ sp.	...	×	
Astarte lucida, *Phil.*	...	...	×
„ ? ovata, *Smith*	...	...	×
„ robusta, *Lycett*	...	...	×
Avicula inæquivalvis, *Sby.* (including A. expansa, *Phil.*)	...	×	×
„ ovalis, *Phil.*	...	...	×
„ pterosphena, *Seeley*	...	...	×

——	St. Ives Brickyard.	St. Ives Rock.	Elsworth Rock.
Lamellibranchiata—cont.			
Cardium Sowerbyi, *Lycett*	...	...	×
Cucullæa clathrata, *Leck.*	...	...	×
„ (Arca) concinna, *Phil.*	×		
„ oblonga, *Sby.*	...	×	×
Exogyra nana, *Sby.*	×	×	
Gervillia acuta (= lanceolata, *Munst.*)	×		
Goniomya literata, *Sby.*	...	×	
Gryphæa dilatata, *Sby.*	×	...	×
Hinnites abjectus, *Phil.*	...	...	×
„ Sedgwickii	...	...	×
Isocardia globosa	...	...	×
Lima duplicata, *Sby.*	...	...	×
„ pectiniformis, *Schloth.*	×	...	×
„ rigida (var.), *Sby.*	×	...	×
„ sp.	...	×	
Lithodomus —	...	...	×
Lucina Beanii, *Lycett*	...	...	×
Modiola bipartita, *Sby.*	×	×	×
„ —	×		
Myacites recurva, *Phil.*	...	...	×
„ oblata, *Sby.*	...	×	×
Myoconcha crassa, *Sby.*	...	×	
Nucula ornata, *Quenst.*	×	×	
Opis —	...	...	×
Ostrea discoidea, *Seeley*	×		
„ flabelloides, *Lam.*	×	×	×
„ gregaria, *Sby.*	×	×	×
„ ? new sp.	...	...	×
Pecten articulatus, *Schloth.*	...	...	×
„ lens, *Sby.*	...	×	×
„ vagans, *Sby.*	...	×	×
„ annulatus, *Sby.*	...	×	
Perna mytiloides, *Lam.*	×	...	×
Pholadomya Phillipsii, *Mor.*	×		
„ ovalis, *Sby.*	...	...	×
„ tricostata, *Seeley*	...	...	×
„ æqualis, *Sby.*	...	×	
Pinna mitis, *Phil.*	×	...	×
„ —	...	×	
Placunopsis, sp.	...	...	×
Plicatula fistulosa, *Lyc.* and *Mor.*	...	...	×
Thracia depressa, *Sby.*	×	×	×
Trigonia clavellata, *Lyc.*	...	...	×
„ costata, *Sby.*	×	...	×
„ elongata, *Sby.*	×		
Unicardium gibbosum, *Lyc.* and *Mor.*	...	...	×
Gasteropoda:			
Alaria bispinosa, *Phil.*	×		
Amberleya armigera, *Lyc.*	...	...	×
Cerithium Damonis, *Lyc.*	×		
„ muricatum, *Sby.*	×		
Littorina muricata, *Sby.*	...	×	
Natica clymenia	...	...	×
Phasinella elegans, *Lyc.* and *Mor.*	...	...	×
Pleurotomoria reticulata, *Sby.*	...	×	×
„ —	...	×	×
Turritella —	...	×	
Cephalopoda:			
Ammonites athletus, *Phil.*	×		
„ Bakeriæ, *Sby.*	...	×	

	St. Ives Brickyard.	St. Ives Rock.	Elsworth Rock.
Cephalopoda—cont.			
Ammonites biplex, *Sby.*	×	×	×
" ? canaliculatus, *Sby.*	...	...	×
" cordatus, *Sby.* (including A. serratus, *Sby.*, and A. vertebralis, *Sby.*).	×	×	×
" dentatus, *Zieten.*	×		
" Duncani, *Sby.* (Langton)	×		
" Eugenii, *Rasp.*	×		
" excavatus, *Sby.* (Over)	×		
" Goliathus	×	...	×
" Henrici, *D'Orb.*	...	...	×
" Hecticus, *Rom.*	×		
" Jason, *Rein.* (St. Neots)	×		
" Lamberti, *Sby.*	×	×	
" Mariæ, *D'Orb.*	×	×	
" oculatus, *D'Orb.*	×		
" perarmatus, *Sby.*	×	...	×
" planicordatus, *Seeley*	...	...	×
" Radisensis, *D'Orb.*	×		
" Rupellensis, *D'Orb.*	×		
" triplex, *Sby.*	×		
Belemnites abbreviatus, *Mill.*	×		
" hastatus, *Montf.*	×	×	×
" obeliscus (?), *Phil.*	×		
" Oweni, *Pratt*	×	...	×
Belemnoteuthis	×		
Nautilus hexagonus, *Sby.*	×		

Kimeridge Clay.

The outcrop of this formation occupies but a small portion of the area, and runs in a narrow belt, partly covered by Drift, from Knapwell by Boxworth, Oakington, and Cottenham to the fens. It is a dark blue clay, somewhat shaly, and enclosing near the surface, in brickyards and other sections, many crystals of selenite. From the clay in the brickyard north of Knapwell some very clear and fine crystals have been taken, great numbers of them being 4 inches or more in length. This is the only exposure of any importance at present occurring along this outcrop of the Kimeridge Clay, and shows 15 feet of dark blue clay with fossils, some of which are filled with iron pyrites. Boulder Clay comes on just above, and a light-coloured hard calcareous band, full of broken shells, occurs at the bottom.

Just south of Knapwell the earth thrown out from a freshly cleaned out pond showed Boulder Clay, with a large heap of dark blue clay (Kimeridge) beneath. There were many fossils and black phosphatic nodules on this heap, their profusion indicating a denudation of the clay resulting in the formation of a "coprolite bed" previous to the deposition of the Boulder Clay.

Similar phosphatic nodules are found on the surface near where the junction line of Kimeridge Clay and Lower Greensand crosses the Huntingdon Road and west of Oakington, showing that a layer of coprolites exists, wholly or in part, between the two formations; but it is probably too attenuated to be of any commercial importance.

The fossils named in the following list were found in the brickyard and pond above noticed.

Kimeridge Clay Fossils (*Knapwell*).

Ammonites biplex, *Sby.*
  „ several species.
Belemnites abbreviatus, *Miller.*
  „ species.
Avicula echinata, *Sby.*
Exogyra nana, *Sby.*
Gryphæa dilatata, *Sby.*
Myacites?
Ostrea deltoidea, *Sby.*, abundant.
  „ gregaria, *Sby.*
Pecten?
Trigonia clavellata, *Young* and *Bird*, cast.
Serpula.
Black phosphatic nodules, in abundance.

CHAPTER III.—CRETACEOUS SERIES.

Lower Greensand.

On the western side of the district embraced in our map the Lower Greensand is covered by the Boulder Clay (except the small exposure near Bourn), from beneath which it emerges with a narrow outcrop east of Boxworth village. It widens somewhat by the Via Devana, and continues, with a nearly uniform breadth of about half a mile, by Oakington to Cottenham, where it opens out over a somewhat wider area; eastward its surface is overlain by river gravel for a short distance, but it reappears near the Plough Inn, on the Ely and Cambridge road, beyond which it passes under the fen towards Upware and Wicken.

The formation mainly consists of brown and yellow sands, with some beds of loam; the sand contains many ironstone concretions, and is frequently false-bedded. Although there are very few sections the area occupied by the beds is well-defined by the redness of the soil, which contrasts strongly with that of the Gault above and of the Kimeridge Clay below.

It might be assumed from the beds making so narrow an outcrop in a flat district either that the thickness of the formation is but slight or that the beds dip at a high angle. The actual dip has not been observed, but it is probable that there is a slight inclination to the S.E. The narrow outcrop affords no real indication of the actual thickness of the deposits because they are overlapped by the Gault, which rests upon them with a slight, and it may be local, unconformity. The Lower Greensand is thinner throughout Cambridgeshire than along any other part of its outcrop, and its thickness may be estimated at about 70 feet. A well at Sawston (*see* p. 164) gives the thickness as 65 feet. In Bedfordshire the sands rapidly thicken to 100 and 200 feet, and when they emerge from the fens in Norfolk their thickness is also much increased.

There are several sections in the small patch exposed by removal of the Boulder Clay from the valley near Bourn, giving rather high angles of false bedding in different directions.

A sand pit about nine chains west of bend in road at Caxton End showed five feet of brown and yellow sand, with some coarse layers about three inches thick, and tabular ironstone concretions with an apparent dip E.N.E. 5°.

In another pit near where the stream crosses the road there is similar sand, but apparently dipping at about the same angle in a contrary direction. Traces of Gault, with phosphatic nodules, may be seen in this section between the Greensand and the Boulder Clay.

In a sand pit at the back of the public-house by the roadside between Bourn and Caxton End brown and yellow sand was seen to a depth of 12 feet, with some coarse layers about three inches thick, and tabular ironstone concretions, with an apparent dip S.W. 28°.

From Lolworth, where the outcrop emerges from beneath the Boulder Clay, sand and loam may be traced across the fields in a westerly direction to Oakington, but no open sections were seen. At Westwick its outcrop is much narrowed by the overlap of the Gault, but the uppermost brown sands are visible in the deep ditches to the N.E., and nearer Cottenham the outcrop from beneath the Gault was observed in a deep ditch by the side of the droveway leading S.S.E. from the road E. of "Cottenham Field." Soft brown sands are visible at the corner of the roads; these pass up into soft yellowish sandy

loam, followed by brown clayey loam, which is succeeded by hard mottled Gault without any very marked line of division, though it is probable that the Gault is somewhat transgressive over the loam.

The area known as Dunstan Field, south of Cottenham, has a brown sandy soil, with occasional fragments of ironstone rock scattered over the surface. The outcrop is again seen in the deep drain just beyond the bridge on the road from Cottenham to Landbeach, where black clay (Gault) is succeeded by dark brown ironstone rock, beyond which, to the N.E., come soft brown sands containing brown phosphatic nodules in some abundance, the whole succession being very similar to some of the sections at Upware and Wicken.

The Black Clay forms a small outlier on the N.W., where the following section was seen in the side of a pond:—

	ft.
Dry lumpy black clay (? Gault) - - - -	$1\frac{1}{2}$
Hard rock with ironstone lumps - - - -	$\frac{1}{2}$
Soft brown sand - - - - - -	2

Similar rock and sands are again seen in a pond to the N.E. three-quarters of a mile west of Goose Farm.

A dark brown sandy loam was exposed in some of the ditches in the fields half a mile south of this spot; it appeared to rise up in a low ridge and to underlie beds of dark grey Gault containing *Belemnites minimus* and phosphatic nodules. This loam may be a lenticular bed near the base of the Gault, or it may indicate a slight unconformity between the Gault and the Lower Greensand.

At a small pond just south of the Plough Inn, on the Cambridge and Ely Road, coarse brown sand enclosing small fragments of phosphatic nodules is visible, and in the ditch leading to Causeway End Farm brown sandy loam was seen passing into mottled yellow and grey Gault.

Yellow loam may be seen under a thin covering of peat to the north of this point, which is only $2\frac{1}{2}$ miles west of the quarry at Upware, in the neighbourhood of which the Lower Greensand phosphates have been so largely worked.

The ironstone concretions mentioned in the above notes are very general in the Lower Greensand, and a description of the mode of their formation may be here reproduced.* They can be seen in every stage in an adjoining area (Sheet 53 S.E.) in a cutting by Sandy Station, on the Great Northern and London and North-western Railways, presenting a nearly vertical section 50 or 60 feet in height. The section consists almost entirely of clean sand, in parts false-bedded, and more or less coloured throughout by the presence of peroxide of iron. The colour of the sand varies from almost pure white, at the lower part, through shades of grey and yellow, to a deep rusty brown. There are here and there layers of hard ferruginous concretions in tabular, spherical, and many other forms, presenting a feature hitherto (so far as the writer is aware) unnoticed, in the gradual passage from soft iron-stained sand to hard complete concretions, exhibiting the various *stages* in the process of their formation. This may be best observed toward the northern end of the cutting, in immediate proximity to and generally beneath the patches of fully-formed concretions, but it is visible also in other parts of the section.

The first step in the process seems to have been the separation of the peroxide into very thin lines resembling stratification, followed by the union of two or more lines, by attraction or chemical aggregation. These thin layers of darker colour retain their linear arrangement until about one-eighth part of an inch in thickness, when the space between them is reduced to about 3 or 4 inches, and they follow the lines of true or false-bedding as the case may be. They then begin to incline towards each other at intervals varying from 4 inches to a foot or more in length, and eventually the bent parts meet, thus enclosing irregular lenticular patches of light-coloured sand. This is as seen in section parallel to the line of cutting, but similar appearances would doubtless be presented in a transverse direction, and the lines of ironsand enclose small masses of material, from which the iron has been removed. In hardness and friability, and in all respects save colour, due to the presence or

* PENNING, *Geol. Mag.*, Dec. II., Vol. III., p. 218.

partial absence of iron, the enclosing and enclosed portions are the same, and the mass can be scraped with equal readiness throughout. But the darker shell gradually hardens and thickens by further elimination of iron from the neighbouring sand, both within and around it, but mainly from within, for the harder the shell has become, the lighter in colour is the nucleus, until it is found almost a pure white in the complete concretion.

These concretionary lumps may be seen in every stage, and in gradations of every stage—in the earlier the sand presents no alteration except a slight change in colour, then the shell hardens somewhat and stands out slightly from the face through weathering. It becomes harder still, and some force is required to break it; lastly, it passes into its hardest and thickest form, when it can be broken only by the hammer, and when it has removed all iron from the nucleus, leaving it perfectly soft and white.

This agrees with the conclusions of Mr. Maw that the formation of such concretions has resulted from segregation independent of chemical combination or mechanical action.*

Gault.

The Gault, in its extension across the southern midland counties, forms an almost continuous valley or low-lying plain between the outcrop of the Lower Greensand and the base of the Chalk escarpment, the uniformity of its level being only interrupted by occasional outliers of newer deposits. In Cambridgeshire, however, the outlying masses of Chalk and Drift are so extensive that the Gault plain is broken up into comparatively small isolated areas, and it is nowhere possible to pass from its upper to its lower line of boundary in a single traverse across the strike. There are, however, numerous wells which pierce the formation from top to bottom, and from them we know that it consists of a stiff bluish-grey clay, somewhat lighter-coloured and more calcareous in its upper part, darker and more argillaceous below, while near the base there is generally a bed of clayey greensand with phosphate nodules.

As the Gault is traced across Cambridgeshire, its upper surface is found to have a considerable northerly or north-easterly slope; this is partly due to the thinning-out of the formation in that direction (as will be hereafter explained), and partly to the diminution in the thickness of the Lower Greensand as it passes towards the north-east.

It is possible that there may also be a low anticlinal or undulation slightly elevating the beds in the south of the county, and thus causing a northerly dip towards Cambridge, but we have no evidence of such an undulation, and the reasons above given are sufficient to account for the facts observed.

In his paper on "Areas of Apparent Upheaval,"† Mr. Topley has shown that such deviations from the horizontal are often due to the thickening or thinning of strata in the direction of dip, and we see no reason why this should not also be true in the direction of strike; thus the rising of the base line of the Gault towards the south-west is probably due to the concomitant increase in the thickness of the subjacent Lower Greensand. If, therefore, the thickening of the Gault itself is added to this, it is clear that its

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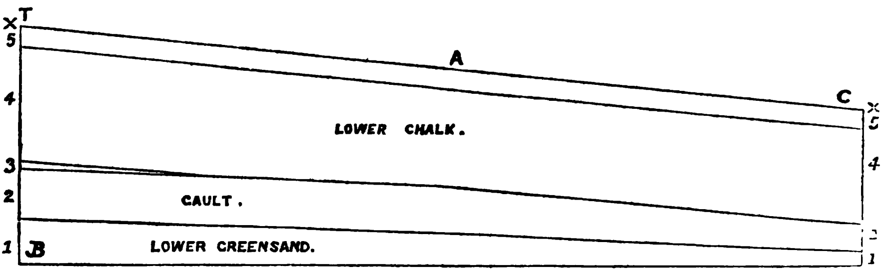
* *Quart. Journ. Geol. Soc.*, vol. xxiv., p. 351.

† *Quart. Journ. Geol. Soc.*, vol. xxx., p. 186.

upper surface must have a considerable slope. A diagram (fig. 1) will make this clear.

Fig. 1.—*Diagram of the Thinning of the Cretaceous Beds along the Strike from S.W. to N.E.*



1. Lower Greensand. 2. Gault. 3. Upper Greensand.
4. Lower and Middle Chalk. 5. Upper Chalk.
T. Position of Tring. A. Position of Arlesey. C. Position of Cambridge.

The general decrease of thickness in a northerly direction may be illustrated by giving the average amount of Gault pierced by wells at various places along the line of strike. Thus between Arlesey and Ashwell (in Sheet 46) the thickness ranges from 180 to 200 feet; at Guilden Morden from 170 to 180; between Bassingbourn and Barrington its average seems to be 150 or 160, but it varies considerably (see *postea*); at Haslingfield its thickness is about 140 feet; near Grantchester and Cambridge it varies between 115 and 130 feet, and in Bottisham Fens from 110 to 120 feet.

Accounts of these and other wells are given in the Appendix.

Besides this gradual attenuation of the Gault, there are also considerable local variations in its thickness, resulting apparently from the unevenness of its upper surface, a character which has probably been produced by the erosion before mentioned. In some instances the varying amount of sandy beds below the Gault may account for the differences in the depth of the wells, but there are usually only a few feet of such sands before the water-bearing stratum is reached, and where the thickness is considerable we have generally been able to ascertain its amount, so that this cause of error is allowed for in the following instances.

Thus while at Morden and Bassingbourn the Gault is about 170 feet thick, at the coprolite works near Wendy only 115 feet, and at King's Bridge near Whaddon it is only 110 feet, but it rapidly thickens again in a northerly direction, for wells at Wimpole, Barrington, and Orwell give a thickness of 170 to 180 feet. In all cases water was found a few feet below the base of the clay, so that in the intermediate district there would appear to be a large hollow or depression in the surface of the Gault, bounded on the north by a long ridge of the same clay, which appears to continue for some distance eastward, for borings at Shelford and Sawston found the Gault still about 170 feet thick.

At several localities the thickness of the Gault is found to be greater where it comes to the surface than at spots in the neigh-

bourhood where *coprolites* are being worked ; thus a well in one of the Gault inliers N.E. of Haslingfield reached water at a depth of 145 feet, whilst another at about the same level, and half a mile N.E., is 150 feet deep, the upper 20 feet being Chalk Marl. This Marl, therefore, would appear to be the complement of the same amount of Gault which had been removed to form the hollow from which the coprolites were being worked out, and where the Gault below was only 130 feet thick (for descriptions of the pits at this locality, see p. 37). A repetition of these phenomena is found in the ridge between Grantchester and Barton, which exhibits flanking outliers of Chalk Marl (see p. 38). The difference of level is here easily appreciable by the eye, for the Gault crosses the highest part of the Barton Road near the third milestone from Cambridge, and the coprolites have been worked down the slopes in both directions, the pits near Full Brook being certainly 20 or 30 feet below this point.

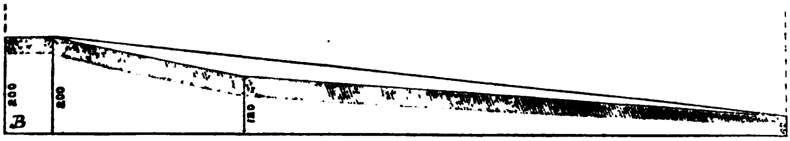
There are several wells in the south part of Cambridge in which the thickness of Gault is unusually great, being given, indeed, as 160 feet, but we have not been able to obtain any satisfactory account of them. No less than four wells in Bateman Street, Russell Street, and Hill's Road are said to have a depth of from 180 to 200 feet, and in these cases great difficulty was experienced in boring through the beds below the Gault, which presented alternations of hard and soft strata without water. The depth at which a supply was ultimately obtained appears therefore to be connected with some peculiarity at the base of the Gault, which may possibly undulate and fill up hollows in the Lower Greensand, as the Chalk Marl does in the upper surface of the Gault. At Cambridge station and along the East Road the Gault is shown to be 120 to 130 feet thick in wells, but at Barnwell it is said to be 140 to 150 feet.

Any one who stands on the surface of the Gault at Barnwell will have little doubt about its being higher than the coprolite bed at Coldham Common, and will see that its slope south-eastward is much greater than can be accounted for by dip alone; Coldham Common, in fact, owes its formation to the existence of a hollow in the surface of the Gault, which is here only between 110 and 120 feet thick. Moreover the clay ridge or "horseback" has been disclosed in several pits south of the Newmarket Road, while towards Fen Ditton its surface slopes so rapidly that coprolites have been followed below the alluvial level (the Gault under Fen Ditton is said to be only 108 feet thick). The surface rises again irregularly about Horningsey, but falls into the hollow of Bottisham Fen.

Beside the class of facts already brought forward, there are others which point in the same direction: thus, further south-west the upper part of the Gault becomes very calcareous, and contains bands of Greensand, so that in Buckinghamshire there is a complete passage up into the Upper Greensand; but in Cambridgeshire there are no such sandy beds, and there is no such passage upwards, the top of the Gault being cut off sharply by an uneven line. All this indicates that the uppermost beds of the formation (belonging to the zone of *Ammonites inflatus*) are absent over the Cambridge area. The following diagram (founded on one given in *Quart. Journ. Geol. Soc.*, vol. xxxi., p. 273) represents a method of

roughly estimating the comparative amounts by which the Gault has been diminished through attenuation and erosion respectively.

Fig. 2.—Diagram of the North-easterly Attenuation of the Gault.



Horizontal scale, 20 miles to an inch; vertical scale, 400 feet to an inch.
The top line represents the probable original surface of the Gault.

The curved line bounding the shading represents the present denuded surface of the Gault.

The evidence above set forth regarding the thickness of the Gault and the irregularities of its surface may be thus summarised: (1), there is a general decrease in its thickness from S.W. to N.E., which appears to be due in part to thinning of the beds, but in part also to the absence, from denudation, of beds like those which characterise the upper part of the Gault elsewhere; (2), there is a complemental filling up of hollows in the surface of the Gault by the overlying Chalk Marl; this is proved by well sections, as well as by facts observed in coprolite pits.

From these considerations, together with the evidence afforded by the presence of derived fossils in the coprolite bed (see p. 29), we cannot but regard the views previously published by one of us as fully confirmed, namely, that the upper beds of the Gault were removed from this area by erosion before the deposition of the Chalk Marl, and that the nodule bed at the base of this marl is the result of such erosion.

Before proceeding to describe the few open sections which exist in the area embraced by this memoir, we would point out that the lower boundary line of the formation is completely hidden for a long distance under the great western spread of Boulder Clay, and since there are no good exposures along the remaining part of its course towards the Fens, the relations of the Gault to Lower Greensand remain very obscure.

From under the Drift-covered country above mentioned three barrier-like ridges of Chalk stretch out over the Gault, and, capped for some distance by Boulder Clay, extend nearly across to the main mass of the Chalk on the east; from this, indeed, they are only separated by the narrow valleys of the Rhee and Cam, these rivers having nearly everywhere cut through to the Gault below. Thus the Gault plain is marked out into four separate areas, and it is only in the northernmost that anything like the whole outcrop of the formation is exposed.

The southerly district, of which Wendy may be considered as forming the centre, is limited by the outcrop of the Chalk Marl near the following places, surrounding it on the N., N.E., and S.E.:—Arrington, Wimpole, Orwell, Barrington, Malton near Meldreth, and Whaddon; coprolite pits at all these places touch the top of the Gault, and at most of them wells pierce through it to the water-bearing Lower Greensand. In boring wells at Whaddon, and also at Guilden Morden and Ashwell to the S.W., a second seam of phosphate

nodules has been found at a depth of 60 or 70 feet below the Cambridge Greensand; and at Wendy and Wimpole notice was taken of a third seam of coprolites near the base of the Gault; this probably corresponds to Mr. PRICE's zone of *Ammonites interruptus*, which appears to be very persistent in its range.

Some brick kilns about a mile south of Wimpole expose a few feet of the clay, but no fossils were found.

Crossing the hills by Orwell and Eversden we pass northward into the second district, which has an average width of about two miles, but contracts westward between the slopes of Boulder Clay; the valley of the Bourn Brook occupies its central line from Kingston till it joins the Cam at the Old Mills near Grantchester, northward the ground again rises up to the gravel-capped ridge which runs through Comberton, Barton, and Grantchester.

The only open section in the area above described is at the brickyard near the bend of the road, half a mile N.W. of Great Eversden; this is dug to a depth of about 20 feet in stiff blue clay, but about 8 feet from the surface there is a thin discontinuous layer of compact red clay, somewhat sandy and traversed by annelid borings which are filled with grey silt.* Some fossils are found, the most abundant being fragments of *Pentacrinus Fittoni*; phosphate nodules also occur, and among them are forms similar to those in the Cambridge Greensand, named *Hylospongia* and *Bonneyia* by Mr. W. J. SOLLAS.

At Haslingfield a well near the church yielded specimens of *Ammonites interruptus* and phosphate nodules at a depth of 154 feet (water being reached at 157). At Daintrees Inn, however, only a quarter of a mile to the N., about 30 feet of dark sandy clay and sand were passed through before "the rock" was pierced and a good supply of water obtained. This is an instance of the varying thickness of the sandy beds at the base of the Gault, for the amount of clay above is nearly the same in both cases. Near Harlton a seam of nodules was met with in the Gault at a depth of 56 feet from the surface.

Passing from this district by Barton, and descending the northern slope of the ridge towards Cambridge, we enter upon a third plain of Gault which contracts westward into a narrowing valley between the Boulder Clay hills, and passes eastward under the gravels of the Cam. Northward the ground again rises towards the road from Cambridge to St. Neots, forming a third ridge, which doubtless was one capped by the Chalk Marl along its whole length, but is now bared of its former covering between the foot of Coton Hill and the high ground occupied by the observatory. There is a brickyard at the corner of the lane leading to Grantchester (barely a quarter of a mile eastward of the stone bridge over the Full Brook), where about 16 feet of stiff dark clay is shown, containing many scattered nodules of phosphate of lime (buff coloured outside, but black within), decomposing nodules of iron pyrites, termed "rugg-stones" by the workmen, also occur; *Ammonites rostratus* and *Plicatula pectenoides* were the only fossils observed.

Eastward from this pit the Gault passes under the gravels of the Cam valley, but comes to the surface again as a narrow strip running north and south through Cambridge, and separating the Barnwell gravels from the lower terrace on which the older part of the town is built. Gault was seen in the foundations for the new pavilion in Fenners Ground, and thence it appears to extend by the Town Gaol across Parker's Piece and the eastern side of Christ's Piece to New Square. Clay was again seen in the foundations of houses here, and we are informed that the greater part of Maid's Causeway also rests upon Gault, which would appear therefore to occupy part of Bull Green until covered by the gravel and alluvium of Midsummer Common.

Under Cambridge the zone of *Ammonites interruptus* has again been proved, for, according to Prof. SEDGWICK "many specimens of *Belemnites minimus* and of broken *Ammonites* were brought up from out of the lower parts of an old well sinking near Cambridge." At the waterworks on the Cherry Hinton Road, brown clayey sand was found underneath the Gault, containing ferruginous phosphatic nodules like those found at West Dereham in Norfolk, only smaller. Again under Coldham's Common about six feet of dark clayey Greensand with nodules intervened between the Gault Clay and the hard rock of the

* See note by Prof. T. R. JONES on a similar bed in Kent, *Geol. Mag.* Dec. II. Vol. iii. p. 117.

Lower Greensand (see Appendix of Well Sections, No. 23). Seams of nodules are also occasionally met with in the Gault (see Wells, Nos. 25, 71).

At Barnwell there are several brickyards, the clay being worked below 10 or 12 feet of Chalk Marl, from the base of which the "coprolites" have been extracted long ago. The largest of these belongs to Mr. Bates, and adjoins the Great Eastern Railway, the section here is as follows:—

	feet.
Disturbed Clunch (or Chalk Marl) - - -	10
Gault. Dark slate-coloured clay drying light grey, with many phosphate nodules, which are mostly disposed along definite lines, but some are scattered throughout. *Plicatula pectenoides* not uncommon -	30 to 40

The "rugg-stones" found here are ball-like masses of a yellowish brown colour generally hollow or filled with a brown powder, the ferruginous crust containing numerous small crystals of selenite; they have doubtless resulted from the decomposition of nodules of iron pyrites. A large flat pebble was found in the Gault here, and is now in the Woodwardian Museum.

The depth of the excavation at Gray's brickyard on the east side of the railway was about 50 feet in 1875, but it has been dug (according to the foreman) to a depth of 66 feet, the clay becoming darker in the lower part. *Plicatula pectenoides* and fragments of pyritized wood were obtained here.

At Watt's brickyard on the west side of the Newmarket Road, the following section was visible in 1875:—

	Feet.
Gravelly soil - - - - - - - -	2
Chalk Marl (the coprolites being worked out) - - -	12
Gault; stiff dark clay drying to a light slate colour; *rugg-stones* and phosphatic nodules are common, the latter are sometimes called "gault-stones" by the workmen - - -	10

The clay in these pits has a slightly gritty feel, and is used without any admixture of sand for making the commoner kinds of brick, but sand is added in manufacturing the better qualities.

On the opposite side of the river, at the corner of the four roads, half a mile N.W. of Chesterton Church, the same clay is worked, the brickyard being opened in a ridge-like island of Gault, which here rises above the surrounding gravel-flats. The workmen stated that they come upon a seam full of phosphate nodules when they dig down in the winter about 17 feet.

North of the ridge running between Coton and Cambridge, which forms the last of the three barriers mentioned in the first instance as crossing the Gault plain, the surface is much encumbered with gravels of various ages, but around Impington the Gault has been denuded of this covering, and the clay is worked in a brickyard a little eastward of the church. The section was thus noted in 1875:—

	Feet.
Disturbed clay, with pockets of gravel - - - -	4
Very hard grey clay - - - - - -	10
Layer containing phosphate nodules ("stony-spit") - -	$0\frac{1}{2}$
Clean dark clay (with fragments of Inocerami) - - -	6

The nodule layer contained many fossils in a more or less fragmentary condition.

Near Lolworth the Gault boundary advances nearly to that of the Greensand; here, however, the rather sharp slope of the ground narrows the outcrop of the latter and unduly increases the appearance of unconformity. But N.E. of Oakington, where the Gault steals over the Greensand, the ground is almost flat, still the former comes nearly to the edge of the latter. Indeed there are indications, in the occurrence of Gault fossils on the surface a mile or two north of this point, that the Gault actually overlaps the Greensand, and rests or has rested directly on the Oolitic Clays; but lithologically the clays

are too much alike to render this point certain in the absence of palæontological evidence. About a mile and a half to the N.W. from Impington the base of the Gault is reached, and in tracing its boundary line across the fields evidences of the basement layer of phosphate nodules were occasionally met with. Thus between Landbeach and Cottenham many *coprolites* and fragments of *Belemnites ultimus* are scattered over the surface of ploughed fields, or may be seen in the sides of newly cut ditches. The same is the case in the fields north of the road to Cottenham, near the deep ditch which drains this district; *Ammonites interruptus* occurred among the fragments picked up here, and the layer may be traced towards Goose Farm till it passes beneath gravel.

There is yet another area where the Gault appears, under somewhat different conditions, viz., in the Fen district east of the Cam.

A quarter of a mile south of Clayhithe, just above the alluvium, a small brickyard gave the section:—

Gravelly soil; with pockets of sand and disturbed Gault below, containing flints and also coprolites from the Greensand outcrop above - - - - - - - -	3–4 feet.
Grey Gault, with a few phosphatic nodules - - -	6–8 „

An *Ichthyosaur vertebra* was obtained here, and other fossils are said to be found occasionally.

Eastward from this point the Chalk Marl comes on and underlies the whole of Horningsey and Ing fens; the coprolites, however, crop out again near Bottisham Load, and N.E. of this the Gault again forms the substratum. By the Load and half a mile N.W. of the village is a small brickyard, and at another near Swaffham Load a new cut gave the following section:—

Peat, underlain in places by pockets of clean yellowish-brown sand, so pure as to be used in the brickmaking - -	2 feet.
Greyish-blue Gault, with scattered phosphate nodules, a band of them occurring at a depth of 12 feet according to the workmen - - - - - - -	8 „

Another small brick-pit, in the Fen about half a mile to the west of this, shows a similar section.

Inliers.

These form an interesting study as they are all produced by local banks or ridges cutting out the Chalk Marl above, and most of them would probably have escaped observation had they not been disclosed by the search after coprolites. Particulars concerning them will be found further on in the description of the coprolite bed, but the positions of the most important may be here indicated. There are three Gault inliers in the outlier of Chalk Marl, north of Haslingfield, and two more under the gravel near Hauxton Mill Bridge. Again near High Hall Farm at Horningsey there is an inlier of considerable extent cutting out the coprolites. The workmen term these patches "dead ground," in consequence of the coprolite bed running "dead" all round them, on the same principle as the name *Rothetodteliegende* is given to a division of the Permian in Germany.

CHAPTER IV.—THE CHALK.

General Description and Classification.

This formation, which occupies so large a portion of our area, has not hitherto received the attention it merits at the hand of geologists. The coprolite bed which forms its base has indeed been minutely studied, and the Cherry Hinton Chalk quarries are known to every student of geology at Cambridge; Prof. Seeley and Prof. Bonney have briefly noticed the lowermost beds seen in this and other pits near Cambridge,* but nothing like a full account of the Cambridgeshire Chalk has yet been written. We hope that the information contained in the following pages will to a great extent supply this deficiency, for we have found it possible to institute a more minute subdivision, and to give a more complete description, of the beds composing the lower and middle portions of the formation than has hitherto been attempted by English geologists except in more limited areas.

The classification we propose is founded upon a consideration both of the lithological and the palæontological characters of the strata, it combines the results of observation in the field and of study in the museum. But it must be understood that this examination has been by no means exhaustive even in the area we have examined. It was not until the larger portion of this had been surveyed that we became convinced of the value and persistence of the divisions, and we have not had any opportunity of following them beyond the limits of the map. (Frontispiece).

From a comparison, however, of our own work with the results obtained by other observers, we feel certain that not only is the existence of zones in the Chalk a well ascertained fact, but that they are remarkably constant throughout the whole extent of the escarpment from Dorsetshire to Cambridgeshire. (See p. 137.)

Mr. Whitaker has briefly described the different lithological characters which the beds of the Lower Chalk present in Buckinghamshire; † and Dr. Barrois has shown that the palæontological zones, which had been established by Prof. Hebert and himself in the North of France, were similarly developed in England. The table (p. 21) will indicate how far our divisions agree with those, of the above-mentioned writers.

With regard to the larger divisions under which the succession of zones may be grouped, we have felt it desirable to revive the general classification proposed by Dr. S. Woodward in 1833 for the Chalk of Norfolk. The Melbourn Rock and the Chalk Rock form such marked breaks in the series that it naturally falls into three main divisions, lower, middle, and upper. We may point out that these exactly correspond with those termed by D'Orbigny, *Cenomanien*, *Turonien* and *Senonien*, as they are defined by Dr.

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* Seeley, *Geol. Mag.*, vol. i. p. 152, and Bonney's Cambridgeshire Geology, p. 48.

† *Quart. Journ. Geol. Soc.*, vol. xxi. p. 398, and *Mem. Geol. Survey*, vol. iv. pp. 40, 44, and 49.

BARROIS.* The lowermost Chalk has been separated by some into Grey Chalk and Chalk Marl; following Mr. WHITAKER we regard as Chalk Marl that only which underlies the Totternhoe Stone, and we agree with Mr. F. G. H. PRICE † in using the term Grey Chalk for the remainder of the division.

TABLE OF CHALK ZONES.

—	Whitaker, 1865, 1872 (Bedford and Bucks).	Classification for Cambridgeshire, 1878.	Barrois, 1876 (Berkshire and Oxfordshire).	
Upper Chalk.	White chalk with flints	Zone of *Micraster cor-bovis.*	Zone à *Micraster cor-bovis.*	**Senonien.**
Middle Chalk.	Chalk rock - -	Chalk Rock -	Zone à *Holaster planus*, 6 to 10 feet.	**Turonien.**
	White chalk, with few flints, but with thin layers of marl, 350 feet.	Zone of *Terebratulina gracilis*, 150 feet, in two divisions; the lower. Vandlebury beds -	Zone à *Terebratula gracilis*, 90 feet.	
		Zone of *Rhynchonella Cuvieri*, 60–70 feet.	Zone à *Inoceramus labiatus*, 60 feet.	
	Hard bedded chalk with thin marly layers.	Melbourn rock -	Zone à *Belemnites plenus* (not identified in Berkshire).	
Lower Chalk. Grey Chalk.	Blocky chalk with curved bedding, 60 feet.	Zone of *Holaster subglobosus*, 80 feet.	Zone à *Holaster subglobsus*, 150 feet (in three divisions).	**Cenomanien.**
	Totternhoe stone, 10–15 feet.	Totternhoe stone, 15 feet.		
Chalk Marl.	Totternhoe marl, 80 feet	Zone of *Rhynchonella Martini*, 50–60 feet.		
	? - - -	Cambridge Greensand.	? Chloritic marl.	

From this it will be seen that we have recognised a greater number of zones or subdivisions than had been previously proposed, the reason of this is that we have acknowledged the existence of several bands of rock which exhibit a marked lithological contrast to the other beds of chalk, and separate zones containing different groups of fossils.

Although these rock-beds are probably only subsidiary to the palæontological zones, and were doubtless formed during the time

* Récherches sur les Terrains Cretacés supérieurs de l'Angleterre et de l'Irlande.
† *Quart. Journ. Geol. Soc.*, vol. xxxiii. p. 431.

that the conditions of the deposit were changing, we wish to call special attention to them at the present time as they afford the only means by which the zones can be satisfactorily traced across the country.

The *Totternhoe Stone* is the lowest of these bands of rock, and its true position was first recognised in Beds and Bucks by Mr. WHITAKER in 1865. Although it is one of the best marked horizons in the whole mass of the Chalk, it possesses no very distinctive palæontological characters; it contains few fossils that are not found either above or below, all that can be said is that fossils are individually more abundant at this horizon, and that certain species seem here to make their first appearance.

The *Melbourn Rock*, the second of these beds, seems to be of even more constant occurrence than the Totternhoe Stone, since it is found throughout the southern counties where the latter does not seem to be everywhere lithologically represented. In Cambridgeshire it always exhibits one or more layers of laminated marl separated by beds of hard rocky cream-coloured chalk; its fauna is scanty, crushed *Rhynchonellæ* and *Ostreæ* being the most abundant fossils, and even the characteristic *Belemnite* appears to be less common than in more southern counties.

The beds for which we have suggested the provisional name of *Vandlebury Beds* are not often seen in section, and may not form so important and persistent an horizon as the others; there appear, however, to be similar hard beds in the Dover Section, about the same height above the zone of *Belemnites plenus*.* Where seen these beds present characters which resemble those of the Chalk Rock. They have not yielded any remarkable fossils, but *Rhynchonella Cuvieri* and *Inoceramus problematicus* are generally common.

The *Chalk Rock*, the fourth of these rocky bands, and perhaps the most conspicious of any, was the earliest to receive notice in England.† Its fauna, which is worthy of detailed investigation, appears to contain a mixture of Upper and Middle Chalk forms together with some that may be peculiar; amongst the last are several Gasteropods. Lists of its fossils have been printed by Mr. E. C. DAVEY, of Wantage, and in Vol. IV. of the Memoirs of the Geological Survey.

As the Cambridge Greensand, the Chalk Marl, and the Totternhoe Stone have been mapped over the country to the S.W., we can pursue the usual plan in treating of these beds, describing the sections from west to east; but for all the divisions above the Totternhoe Stone it will be more convenient to commence the description of each zone where it is intersected by the line of section (Plate 5), and having indicated the exposures of similar beds along the outcrop towards the S.W. to return to the starting point and trace the zone to the N.E.

Such outliers as we have recognised to belong to any of the divisions will be mentioned after the main outcrops have been described.

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* See Memoirs of the *Geological Survey*, vol. iv. p. 32.

† *Catalogue of Rock Specimens* in the Museum of Practical Geology. Ed. 2, 1859, See also *Quart. Journ. Geol. Soc.* vol. xvii. p. 166, and *Mem. Geol. Surv.* fol. iv. p. 46.

Mr. Allen succeeded in making a considerable collection of fossils from localities indicated by ourselves, and thus supplied us with the material for the lists of fossils given in the following pages. In the case of the Cambridge Greensand and Totternhoe Stone, however, this has been supplemented by means of fossils in the Woodwardian Museum.

LOWER CHALK.

Chalk Marl.

The Chalk Marl forms a low undulating strip of ground, varying in breadth according to the slope of the land, between the irregular outcrop of the Gault and that of the Totternhoe Stone, which forms the base of the Grey Chalk. It lies for the most part on the eastern side of the Cam and Rhee Valleys, and has been traced from the neighbourhood of Ashwell, in Sheet 52, through the N.W. corner of Sheet 47, and into Sheet 51 as far as Reach and Burwell on the borders of the Fen country.

There are, however, numerous outliers to the westward of this line, and one of these occupies a considerable area in the south-western corner of Sheet 51; this may, indeed, be connected with the main mass by a narrow neck of marl near Harston, where a depression in the surface of the Gault allows the "coprolite bed" to pass below the level of the alluvium, but the river Rhee cuts down to the Gault, both above and below this point, so that the tract above mentioned is practically an outlier. From Harston it widens out by Barrington and Haslingfield, and the higher central portion of the ridge is formed of Grey Chalk capped with Boulder Clay; the whole extends westward between Wimpole and Eversden, and stretches into Sheet 52, where it must underlie the glacial clay for several square miles.

The coprolite bed which forms the base of the Chalk Marl has been worked along the whole length of its outcrop, and all round the above mentioned outlier; several outlying patches, with more r less of the overlying marl, are to be found in the neighbourhood of Wimpole, Orwell, Barrington, and Haslingfield.

The ridge-like outliers to the northward, west of Grantchester and Cambridge, have already been mentioned in describing the outcrop of the Gault, and these likewise stretch westward under the Boulder Clay of Madingley and Hardwick; they are clearly the remnants of an extensive promontory of Chalk Marl which occupied the west side of the Cam valley in Pre-Glacial times, but which has been broken up and removed by Post-Glacial erosion and denudation.

There is always a considerable quantity of water in the lowest part of the Chalk Marl held up by the Gault below, but no strong springs are thrown out like those from the overlying Totternhoe Stone.

The Cambridge Greensand.

Character and Mode of Occurrence.

This basement bed has long been known by the name of the "Cambridge Greensand" or "Coprolite Bed." It is a clayey marl, to which a greenish colour and a sandy texture is imparted by the presence of numerous Glauconite grains, and its lowermost layer always contains an accumulation of the phosphatic nodules, commercially known as "coprolites."

The Cambridge Greensand has been traced north-eastwards from Harlington in Bedfordshire into Cambridgeshire, and has everywhere been found to present similar characters. Its constitution varies slightly in different places according as one or other of its several ingredients, clay, marl, or glauconite, happens to preponderate, but everywhere the green grains become fewer and fewer in an upward direction, so that it gradually passes into the greyish beds of the Chalk Marl.

For a long time it was considered as Upper Greensand, and was supposed to be the diminutive representative of the series of greensands, chert-beds, and firestones so well known in the south of England; it has been shown, however, that these die out in a northerly direction before the Cambridge Greensand commences,* and it is much more probable that this is the homotaxial equivalent of the so-called Chloritic Marl, which is generally separated from the Upper Greensand by a band of phosphatic nodules.† The earliest notice of the bed is by Prof. HAILSTONE in 1816,‡ who describes the section in the brick pits near Castle Hill as exhibiting a passage from Marl through Greensand to the Gault, and speaks of the coprolites as "irregular dark brown nodules of a ferruginous indurated marl."

In 1836, FITTON remarked,§ "This formation here differs from that of some of the more southern counties in its much smaller thickness, in the absence of chert, and the comparative rarity of green particles which are here confined to a stratum not more than 18 inches thick, by which the lowest beds of the Chalk are separated from the Gault, as is well seen in the section exposed at the Castle Hill, Cambridge. The presence of this green bed, however, is remarkably constant, and it contains many fossils, some of which are common to this formation and the Chalk; but others, at least in this country, are confined to the sand." In this observation Dr. FITTON anticipates the subsequent division of its fauna into Chalk and Gault elements.

In 1845 Prof. SEDGWICK describes the bed "as only a few inches thick, and above it there is sometimes an ambiguous deposit of a few feet which forms a passage into the Lower Chalk. It is not true, as has formerly been stated, that the Chalk Marl forms a passage into the Gault, for the Upper Greensand makes a natural break between them."‖

* JUKES-BROWNE, *Quart. Journ. Geol. Soc.*, vol. xxxi. p. 256.

† TOPLEY, Geol. Survey Memoir on the Geology of the Weald, p. 157, and BARROIS, Recherches sur les Terrains Cretacés Supérieurs.

‡ *Trans. Geol. Soc.*, vol. iii. p. 243.

§ *Trans. Geol. Soc.*, part 2, Vol. iv. p. 306.

‖ *Rep. Brit. Assoc.-Trans.*, Sections, p. 40.

This remark is very true; there never occurs anything like a passage from the one formation into the other; on the contrary, the line of demarcation between Gault and Greensand is always sharp and clear, and the surface of the Gault is frequently uneven, exhibiting hollows and undulations which have evidently been produced upon it before the deposition of the overlying nodule bed. All succeeding observers have noticed the existence of these irregularities,* and their influence on the outcrop of the bed is very plainly shown by the line on the Geological Survey map, which does not at all follow the contour of the land, but rises and falls perceptibly within very short distances.

The numerous small outliers and patches which exist everywhere on the borders of its outcrop, and consist of the coprolite bed with more or less of the overlying marl, almost always rest in hollows of the underlying Gault, and it is doubtless to this circumstance that they owe their preservation.

It is worthy of remark that the coprolite bed, as such, *i.e.*, enclosing phosphatic nodules, never occurs quite at or even near to the surface. When the bed rises to within about three feet of the surface, it ceases to be continuous, and lies in hollows, which are generally steep-sided, and resemble "*pot-holes*." An area containing coprolites is more valuable when they "lay fleet" (within a short distance of the surface), because less expensively worked, than when they occur at a considerable depth.

The nodule bed itself rarely exceeds a thickness of 10 inches, but the Greensand or Glauconite Marl generally extends upwards for another 5 or 6 inches; when, however, there are any undulations in the surface of the Gault, the stratum of Greensand is always seen to be thinner on the top of the rolls, and thicker in the hollows, being frequently from 18 to 24 inches deep in the latter. The same is generally the case with the layer of phosphatic nodules; in some few instances it appears to exhibit little difference in thickness, but as a rule there is a greater accumulation in the troughs, and occasionally it is entirely absent on high rolls or ridges.

Included Erratics.

Another proof of the existence of currents during the deposition of the Cambridge Greensand is the frequent occurrence of extraneous rock fragments in the bed, which are sometimes so large as to cut out the nodule seam altogether. Their existence was first pointed out by Prof. SEELEY, in his paper on the "Rock of the Cambridge Greensand,"† and he notices some of the varieties which occur as well as the angular outline, which they often present. A large number of these stones and erratics were subsequently collected and placed in the Woodwardian Museum, and some were described in a paper read before the Geological Society in 1872.‡ Among them are fragments of granite, basalt, hyperite, gneiss, quartzite, schist, sandstone, and purple grits, many resembling Scotch and

* SEELEY, *Geol. Mag.*, vol. lii., p. 306; JENYNS, *Proc. Bath, Nat. Hist. Club*, vol. i., p. 9. BONNEY, *Proc. Geol. Assoc.*, vol. iii., p. 14.

† *Geol. Mag.*, vol. iii., p. 303.

‡ SOLLAS and JUKES-BROWNE, *Quart. Journ. Geol. Soc.*, xxix. p. 11.

Norwegian rocks, and the authors maintained that the agency of ice must be called in to account for the presence of so many stones and angular blocks at so great a distance from their parent masses. Prof. BONNEY had also come to the same conclusion regarding them.* Two specimens more recently obtained are thus described by Mr. RUTLEY. (1.) A quartz porphyry, with a compact pink felsitic matrix containing porphyritic blebs of quartz and decomposed crystals of felspar, probably orthoclase. (2.) A dark grey aphanitic rock with a few porphyritic felspar crystals, probably a felstone, but may be a basalt. With these are fragments of granite and red schistose sandstone, and a lump of pinkish talcose schist, nearly as soft as soapstone. In all some 30 fragments, large and small, were collected in 1875 from coprolite pits near Cambridge.

Nature of the Coprolites.

The nodules themselves are usually dark brown or nearly black outside, but internally of a creamy grey or light brown; amongst them there are some few of a dull buff, which probably do not contain so much phosphate of lime as the darker stones. A good aggregate sample of Cambridge coprolites contains from 56 to 58 per cent. of this phosphate, and they are consequently richer than the Neocomian nodules, which seldom average above 50 per cent., and better than those found in the Red Crag, which vary greatly, but generally contain from 52 to 56 per cent. of the phosphate.

Ordinary commercial analyses of coprolites often indicate a higher percentage than the above, but Dr. VOELCKER† explains that when the amount of phosphate is determined in the usual way by precipitation, the fluoride of calcium which the nodules contain is thrown down with the precipitate, and consequently the amount of tribasic phosphate of lime is stated 3 or 4 per cent. higher than it is in reality. Dr. VOELCKER has therefore ascertained the true proportion of this phosphate in several samples by determining the percentage of phosphoric acid, and calculating the amount of "*bone earth*" or tribasic phosphate to which this acid is equivalent We append three of the detailed analyses thus made‡:—

Moisture and organic matter	4·01	3·52	3·80
Lime	45·39	46·60	43·68
*Phosphoric acid	26·75	27·01	26·05
†Carbonic acid	5·13	5·49	18·70
Oxide of iron	1·87	2·08	
Alumina and magnesia, &c.	4·62	2·47	
Sulphuric acid, fluorine, &c.	6·01	6·79	
Insoluble siliceous matter	6·22	6·04	7·77
	100·00	100·00	100·00
*Equal to tribasic phosphate of lime	57·12	58·52	56·87
†Equal to carbonate of lime	11·66	12·47	—

* *Proc. Geol. Assoc.*, vol. iii., p. 18, and *Cambridgeshire Geology*, p. 33.
† *Journ. Roy. Agric. Soc.*, vol. xxi., p. 358.
‡ See *Journ. Roy. Agric. Soc.*, vol. xxi. p. 358, and ser. ii., vol. xi. p. 404.

The analysis originally quoted by Prof. SEELEY, and subsequently by Prof. BONNEY, contains less than the ordinary amount of phosphoric acid, viz., 25·29 only, equal to 54·89 of the phosphate; another more recently made by Dr. VOELCKER, yielded an unusually large amount, equal to 63·60 of the phosphate, so that the quality of the nodules is found to vary considerably.

We have elsewhere remarked upon the similarity between the Cambridge nodules and those which occur in the upper portion of the Gault; it is satisfactory, therefore, to find that their chemical composition is identical, and that the amount of phosphate of lime averages nearly the same in samples from both formations. We have been furnished with the following analyses of Gault phosphates; the first two are from the Lower Gault of Bedfordshire, and for them we are indebted to Mr. J. B. Lawes, of St. Albans; the third is a sample from the nodule bed in the Upper Gault at Slapton, Bucks, and was supplied by Mr. W. Wilkerson, of Leighton Buzzard

——	I.—By Dr. Voelcker.	II.—By Mr. B. Dyer.	III.—By Mr. A. Sibson.
Moisture and organic matter	3·79	5·85	·68
Lime	46·13	44·44	46·11
*Phosphoric acid	27·68	27·27	30·04
Oxide of iron, carbonic acid, alumina, magnesia, &c.	17·76	16·01	17·04
Insoluble siliceous matter	4·64	6·43	6·13
	100·00	100·00	100·00
*Equal to tribasic phosphate of lime	60·43	59·53	65·58

In comparing the two sets of analyses it must be remembered that the latter were only made for commercial purposes, and consequently that the calculated amount of tribasic phosphate is greater than the reality, for the reason given before; if due allowance be made for this it will be seen that the actual amount would average about the same in both cases.

Origin of the Nodules.

As regards the mode in which the phosphatic nodules have originated, it may be remarked in the first place that a considerable proportion of those in every washed heap can easily be recognised as fossil organisms. The bones and teeth of reptiles and fishes, and the casts of Mollusca, Crustacea, Echinoderms, and Corals, speak for themselves, though all these are often worn, broken, and fragmentary; of the rest many have recently been proved to be phosphatised sponges,* and we fully believe that all, in common with other phosphatic nodules, have originated in the decomposition of organic matter on the sea bottom. It is known that phosphate of lime is soluble in carbonated water, and that from such solution it is precipitated by ammonia, which is one of the products of the decomposition of animal matter; it seems most probable, therefore, that such phosphate as is contained in the

* SOLLAS, *Quart. Journ. Geol. Soc.*, vol. xxix. pp. 63 and 76.

water permeating the mud of a shallow sea-bottom should be concentrated at those points where ammonia is being evolved.*

Many facts have been noticed showing the connexion between decaying animal matter and the formation of the calcic phosphate ;† the under surfaces of Crustacea, for instance, are generally covered with phosphate, while the carapace is free from it; the calyces of Corals are often filled up in a similar manner, and the bases of sharks' teeth are sometimes completely embedded in the mineral, while their polished surfaces are clean and free.

In these cases and in others where some shell happens to have been entirely enclosed in a nodule, the hard parts remain as an evidence of its mode of formation, but when the decaying organism possessed no hard test or skeleton an entirely amorphous and homogeneous nodule would be the result.

On this subject some remarks by M. L. GRUNER on the phosphates of the Perte du Rhone‡ may be translated as being in some measure applicable to those from the Cambridge Greensand; he says:—"When the aperture of the shell communicating with the exterior is narrow, as in the small Echini and the inner chambers of Cephalopoda, the cast consists of a dense and compact homogeneous mass, composed of an intimate mixture of phosphate and carbonate of lime ; the tint is then a clear blonde or yellow brown, more rarely black, according to the proportion of organic matter mixed with the phosphate."

"On the contrary, when the communication with the interior of the shell is easier, the cast is more or less filled with grains of black or green sand; this is the case with the large external chambers of Cephalopoda, with many Gasterpods and with Bivalves. The amount of phosphate is then also more or less diminished, and this is also the case when the calcareous shell is relatively thick." Four of the analyses upon which he founds this opinion are given below :—

——	Calc. Phosph.	Calc. Carb.	Glauconite.
Echinus - - -	70·60	17·40	12·00
Nautilus (inner chamber)	65·30	29·60	5·00
Ammonite (large fragment) -	46·20	22·80	31·00
Inoceramus - - -	38·25	33·55	28·20

From these data he concludes that the phosphate must have come from without in a state of solution, and cannot have been introduced in the form of a soft paste through the orifices of the shell or test, since "we should then find the green grains of the encasing sand constantly present instead of their being only in the more open shells." He attributes the production of these phosphate beds "to the prolonged accumulation of the remains of animals which lived and died upon the spot."

* See BONNEY, in *Proc. Geol. Assoc.*, vol. iii. p. 14.

† See *Geol. Mag.*, vol. x. pp. 269, 270, and *Quart. Journ. Geol. Soc.*, vol. xxix. pp. 54, 60.

‡ *Bull, Soc. Géol. de France,* ser. ii. t. xviii. p. 62.

As regards the Cambridge phosphates it is certainly the case that the casts of Echinoderms, small Gasteropods, close-fitting Bivalves, and the chambered portions of Cephalopods afford the most compact and homogeneous phosphatic substance, while green grains occur in that which occupies the larger Bivalves, the calyces of Corals, and the more open parts of other organisms.

Such facts likewise negative the possibility of the phosphate having been subsequently introduced after the formation of the deposits, and Mr. NESBIT's analyses of the nodules from the Chloritic Marl in the Isle of Wight, showing that there is always more calcic phosphate in the interior of a nodule or cast than there is in the outer part, confirms this conclusion.

It must not be supposed, however, that the nodules of the Cambridge Greensand have originated in the bed where they are now found. We have already noticed the absence of the upper beds of the Gault in Cambridgeshire, and also the evidences of erosion which its surface presents. These circumstances, taken in conjunction with the waterworn condition of most of the "coprolites," and the fact that the majority of the fossils belong to Gault species. lead to the conclusion that they have been derived from the underlying formations. Moreover, the nodules themselves, both dark and light coloured kinds, are exactly similar to those found in the nodule beds of the Upper Gault, or zone of *Ammonites rostratus*, in Kent, Surrey, and Buckinghamshire; these beds always contain a quantity of glauconitic sand, so that the presence of green grains in some of the Cambridge phosphates offers no difficulty to the acceptance of such a derivation.*

Fossils.

We are thus brought to a consideration of the fossil contents of the Cambridge Greensand, which are divisible into two groups, exhibiting marked differences in their palæontological affinities as well as in their states of preservation and fossilization, the one group of fossils has been derived from the Gault, the other is proper to the bed itself.

The large derived fauna, comprising upwards of 200 species of invertebrata, together with many reptiles and fish, was for a long time looked upon as indigenous to the formation, and its members were catalogued as Upper Greensand forms; as such an assignment involves a double error, and as they properly belong to the Upper Gault, or zone of *Ammonites rostratus*, they should be considered as representing that zone in Cambridgeshire, and not as belonging to any equivalent of the Warminster Greensand or of the Chloritic Marl. A full list of these fossils will be found in the Appendix.

The following is a list of the fossils which appear to belong to the glauconitic marl itself, and most of these range upwards into the Chalk Marl of Cambridgeshire and other counties:—

LIST of FOSSILS from the CAMBRIDGE GREENSAND.

Acanthopholis eucercus, *Seeley*.
„ stereosaurus, *Seeley*.

* See F. G. H. PRICE, *Quart. Journ. Geol. Soc.*, vol. xxx. p. 353, and JUKES-BROWNE, *Ibid.* vol. xxxi. pp. 270, 271.

Anoplosaurus curtonotus, *Seeley*.
„ major, *Seeley*.
Ichthyosaurus campylodon, *Carter*.
Macrurosaurus semnus, *Seeley*.
=Acanthopholis platypus, *Seeley*.
Ornithocheirus Carteri, *Seeley*.
„ Fittoni, *Owen*.
Plesiosaurus (several species).
Polyptychodon interruptus, *Owen*.
Testudo cantabrigiensis, *Seeley* (M.S.).

Edaphodon Sedgwickii, *Ag*.
Enchodus halocyon, *Ag*.
Notidanus microdon, *Ag*.
Otodus appendiculatus, *Ag*.
Protosphyræna ferox, *Leidy* (Saurocephalus lanciformis, *Harlan*).*

Belemnites ultimus, *D'Orb*.
Anomia transversa, *Seeley*.
Avicula gryphæoides, *Sow*.
Lima globosa *Sby*.
„ ornata, *Ether*.
Ostrea cunabula, *Seeley*.
„ frons, *Park*.
„ lagena, *Seeley*.
„ vesicularis, *Sby*.
„ (Exogyra) haliotoidea, *Sby*.
Pecten orbicularis, *Sby*.
Plicatula inflata, *Sby*.
„ minuta, *Seeley*.
„ sigillina, *Woodward*.
Radiolites Moretoni, *Mant*.
Teredo amphisbæna, *Goldf*.

Argiope megatrema, *Sby*.
Kingena lima, *Defr*.
Rhynchonella lineolata, *Phil*.
„ mantelliana, *Sby*.
Terebratula biplicata, *Sby*.
„ semiglobosa, *Sby*.
„ sulcifera, *Morris*.
Terebratulina rigida, var.
„ striata, *Wahl*.
„ „ var. triangularis, *Ether*.
Thecidium Wetherellii, *Morris*.

Astrogonium, sp.
Cidaris Bowerbankii, *Forbes* (spines).
„ Dixoni, *Cotteau* (spines).
„ gradata, *Seeley*.
„ Sedgwickii, *Seeley*.
„ vesiculosa, *Goldf*. (spines).

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* It is much more difficult to separate the derived Vertebrate remains from the others, than it is in the case of the Invertebrata, and it may be that more species will have to be added to the above list. The bones and teeth of *Ichthyosaurus* often occur in associated sets, and in a friable condition, hardly mineralised; many of the Dinosauria have also been obtained in associated series, and these bones are generally preserved in a very light-coloured phosphate; such remains may certainly be regarded as belonging to the bed in which they are found.

Discoidea cylindrica, *Lam.*
,, subucula, *Klein.*
Echinocyphus impressus, *Seeley.*
Goniophorus lunatus, *Ag.*, var minutus, *Seeley.*
Holaster subglobosus, *Leske.*
Pentacrinus Fittoni, *Austen.*
Salenia Woodwardii, *Seeley.*

Palæga Carteri, *Woodward.*
Pollicipes arcuatum, *Dar.*
,, glaber, *Sby.*
,, unguis, *Sby.*
Vermicularia umbonata, *Mant.* (var. of).
Micrabacia coronula, *Goldf.*
Onchotrochus Carteri, *Duncan.*
Pharetrospongia Strahani, *Sollas.*
Parkeria (large species).

Description of Sections.

In describing the sections presented by the various "coprolite pits" which came under our notice, it will be convenient to treat firstly of those occurring along the main line of outcrop from S.W. to N.E., and secondly, of the outliers which lie to the W. and N.W. of this line, on the opposite side of the continuous valley formed by the Rhee and Granta; including under the latter head the peninsula-like mass stretching westward from Harston and Haslingfield.

Main Outcrop.

The nodule bed, forming the boundary line of the Chalk Marl enters Sheet 47 half a mile S.W. of Bleak Hall, near Bassingbourn, and passes into 51 S.W. by the 42nd milestone on the Roman way called Ermine Street, west of Whaddon. There are still many workings in the neighbourhood of Bassingbourn and Whaddon, but none called for special remark till we reach King's Bridge North of the latter place, where the bed has been followed 10 or 12 feet below the level of the alluvium on each side of the stream, although both westward and eastward of this spot its banks consist of Gault. The same was found to be the case near Malton Farm, and thus the extreme unevenness of the surface on which the nodule-bed rests may be perceived from a mere inspection of the map. The irregularity of the line further N.E. testifies to the same fact, for it runs in and out without conforming in any way to the contours or natural features of the country; its behaviour is in fact the direct result of the hollows and ridges existing in the surface of the Gault.

Near Harston, the coprolites have been extensively worked, and are now exhausted from the land on the eastern side of the river; a pit in the field S.W. of Hauxton Mill Bridge showed the following section in 1875:—

		Feet.
Evenly bedded sand and gravel	- -	3 to 10
Grey marly chalk ("clunch")	- -	12 to 6
Greensand bed, with "coprolites"	- -	1

A few yards to the westward of this pit the basement bed had cropped out round a patch of dead "ground," which thus formed an inlying ridge of Gault (beneath a thin covering of gravel) about 20 yards broad from north to south, and not more than 100 yards long. The bed has also been worked on the east side of the road, and the workmen stated that there was a similar small patch of dead ground on this land. North of Hauxton Bridge the coprolites have been worked out for some distance, but nearer Trumpington we believe they have not yet been disturbed, and the outcrop passes beneath the gravel forming the right-hand bank of the river near "Byron's Pool."

North of Trumpington, on Major Pemberton's property, the phosphate bed has been worked for many years, the trench which was open in 1875 ran nearly

N. and S. at a distance of about a quarter of a mile from the main road, and the ordinary depth was from 18 to 20 feet, but the surface of the Gault was gently undulating and towards the northern end rose up in a large roll which brought the nodule seam to within 13 or 14 feet of the surface of the ground. The general direction of this ridge was N.W. and S.E., and the foreman stated that it had continued since they first opened the pit (a distance of about 150 feet when these notes were taken), but its height had been gradually diminishing as the trench was cut back eastward. The seam of Greensand was certainly thinner on the top of the roll, while in the hollow on one side the dark sandy marl formed a tolerably well-marked bed nearly two feet thick, the lower half being full of the black phosphate nodules, in other places the thickness of the sandy seam was not more than one foot, only 8 or 9 inches of this being occupied by the nodule bed. Thus the general section was as follows:—

	Feet.
Greyish-white clunch, with irregular pockets of gravel 2 or 3 feet deep - - - - - -	6
Dark grey clunch (lumpy) - - - -	12
Dark glauconitic marl with nodules - - -	1

Marl with coprolites was seen in the ditch or watercourse just south of Mr. . .'s farm, and the outcrop of this bed must pass under the gravel across the road from Trumpingion to Cambridge, near Willer's Nursery; in 1876 a pit was opened near Vicar's Brook, a little south of the point where it crosses the road, and the section shown was the following:—

	Feet.
Fine gravel and sand - - - - - -	6
Clunch, wet and dark-coloured - - - -	8
Marly greensand, looking dark and muddy - -	1

There were strong springs at the base of the gravel, and much difficulty was experienced in pumping out the water.

In 1875 a trench was made for the purpose of laying a drain between the New Pavilion in Fenner's Ground, Cambridge, and the main pipes in Hills Road, this intersected a narrow tongue of marl with coprolites, as shown in fig. 22, p. 102.

The main line of outcrop must therefore run by St. Paul's Church, and across the fields to the cemetery; N.E. of this the bed has been worked out under the gravel.

Eastward, where the ground sinks towards Coldham Common, numerous pits have from time to time been opened, and the coprolite bed under this area is now nearly exhausted. It is only necessary to describe one or two of the sections here shown; the following was seen in a pit on the west side of the cart-road about a quarter of a mile N.E. of Polecat Farm:—

	Feet.
Greyish-white marl - - - - - -	10
Greenish-grey, intermixed with greyish-blue clunch, the beds of the latter being chiefly in the lower part, both hard and lumpy - - - -	9
Dark sandy marl, with coprolites - - about	1

Another pit near the brook to the S.E. showed an inclined surface of Gault, the clunch being 20 feet deep at the N. end and only 15 feet at the other, the upper 6 feet of the marl were soft and clayey, becoming rather harder and more lumpy below, the next 8 or 10 feet presented a rough face, consisting of lumps of hard bluish-grey clunch set in a loose clayey matrix; there were many cracks and open interstices stained with iron or manganese. Below the rock became more homogeneous, and passed down into hard marly greensand with coprolites, breaking into lumps; underlying this was a bed of very dark clayey marl, and then the usual seam of dark clayey greensand with nodules, resting on the Gault. The foreman, Henry Coe, stated that the nodule bed was frequently double, as above described, and that the intervening seam was often a dark clay resembling Gault; when double, the thickness to the top of the upper bed would be about 18 inches.

Under Coldham's Common the coprolites have been worked at varying depths, down to 24 feet near the brook. We have already mentioned (p. 18) that they have been taken out from under the marl in the brickyards at Barnwell, and that they run up here to a much higher level than their horizon under the Common. This rise, indeed, brings the Gault to the surface in the hollow between the railway and the brook, but the marl passes down again below the alluvium north of the bridge by the old paper mill.

In 1876 the northern slope of this Gault ridge was visible in a pit on the east side of the brook, and south of the Newmarket Road; at the back of the garden-wall the Gault lay at a depth of 25 feet, and thence its surface sloped rapidly up in a S.S.E. direction, the nodule bed cropping out near the bottom of the same field, but in the S.E. corner of this shallow pockets with nodules were found. The foreman estimated the length of the trench at about 200 feet, so that the apparent inclination of the surface was about 7°, but he believed the deepest slope to be towards the N.E. or N.N.E. The slope was fairly even and regular, and the thickness of the Greensand seam was greatest in the deeper part of the pit; but the portion of this containing the coprolites did not seem to vary, but kept much the same thickness throughout. The section here was similar to that represented in Fig. 6.

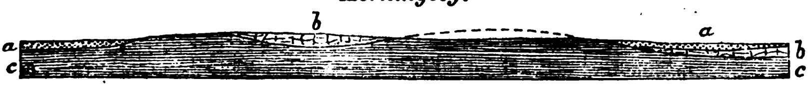
South of the farm to the east there were workings in 1874–5, about 10 or 12 feet deep, these must have been on the southern side of the ridge, which appears to be continuous for some distance. It was again proved at pits about a quarter of a mile south of the old turnpike at the corner of the road to Ditton; the trench here completely intersected it from N.N.E. to S.S.W., and showed the nodule-bed dipping down a slope of Gault in each direction, the top of the ridge being between 7 or 8 feet of the surface of the ground.

From the top of the ridge above described the surface of the Gault, and with it of course the Cambridge Greensand, slopes northward till it is found at a depth of 33 feet under Fen Ditton. A quarter of a mile S.W. of the church, and near the level of the alluvium, it was touched at a depth of 15 feet, it would appear therefore to pass under the alluvium and the river-bed, it certainly reappears on the western bank, and has been worked under the fields by Ditton corner. Workings also have recently been opened (1878) on the alluvial level N. of the Plough Inn at Ditton.

About Horningsey there are extensive excavations, but nothing of special interest was seen in the trenches. We were informed by Mr. Fyson, of Horningsey, that his father was one of the first to dig and wash the coprolites soon after the discovery of their commercial value by Professor HENSLOW; many thousand tons have been raised from this parish.

Between High Hall and Herdwalk Common there is a Gault inlier forming a considerable area of dead ground, being about 500 yards long and nearly 200 wide at the south end. A trench opened in 1875 showed the greensand cropping out and dipping eastwards beneath 5 or 6 feet of fine sandy gravel, which became thinner as the nodule bed sank under the Marl towards the Fens.

Fig. 3. Section across the Fields about Half a Mile N.W. of Horningsey.



Scale 8 miles to an inch.

a. Gravel. *b.* Chalk Marl. *c.* Gault.

At the east end of the trench the section shown was this:—

	Feet.
Black fenny soil - - - -	1
Gravel and sand in pockets - - -	3
Greyish white clunch - - - -	5
Sandy vein with cops - - - -	$\frac{3}{4}$

Northward of this many irregularities and ridges were to be seen in the surface of the Gault when disclosed by the workings for coprolites. (See *Quart. Journ. Geol. Soc.*, xxxi. p. 260.)

A small outlying patch was worked close to the lane leading northward from Clay Hythe, in a hollow, the maximum depth of which was 7 or 8 feet; an irregular ridge of Gault separated this from the deeper excavations to the eastward, where the nodule bed sloped gradually down towards Bottisham Fen. Under this Fen the bed has been proved in many places to the S.W. of the Bottisham Lode, so that its outcrop could be entered on the map with considerable accuracy; the extreme irregularity of this line indicates how uneven is the surface on which it rests, and a further demonstration is afforded by the fact that instead of continuing its normal dip towards the S.E., the surface of the Gault *actually rises in this direction*, and is exposed as a long narrow strip between the fen-edge and the outcrop of the Chalk Marl near the village called Bottisham Load. This feature produces the curious phenomenon of an outlier existing at a lower level than that occupied by the outcrop of the main mass; this small patch lies under the fen nearly a mile N.E. of Long-Meadow Farm. Three quarters of a mile north of this farm the outcrop again passes under the fen and crosses the Swaffham Load.

The phosphates have been extracted from underneath a large portion of Swaffham Fen, but many pits were open in 1875–6, with depths varying from 3 to 15 feet. The section exposed in one of them at the corner of the roads, named respectively "White" and "Black" Droveways, is given below:—

	Feet.
Black peaty soil - - - -	1
Fine yellow silty sand - - - -	4
Clunch, with coprolites at the base - -	7

The greensand thrown out had very little admixture of clay, and dried into laminated greenish white lumps. Similar sections were to be seen in the pits southward and northward, and the phosphate nodules extracted from all of them exhibited different characters to those obtained nearer Cambridge. There was a much greater proportion of light-coloured phosphates, and the fossils which occurred amongst these had not apparently been subjected to much rolling, but retained their shells in a more perfect state than usual, *Terebratulæ*, *Rhynchonellæ*, and *Exogyræ* being especially common and well preserved; *Radiolites Moretoni* and *Pharetrospongia Strahani* from the Marl itself are also abundant in this neighbourhood.

Amongst the darker nodules there are some which have a greenish exterior, and the whole assemblage has a different aspect from those to the south, as if resulting from the erosion of differently constituted beds in the Gault.

In connexion with the peculiarities presented by these nodules it may be mentioned that one of us, when accompanying Professor BONNEY some years ago, saw an excavation near Reach, where a second coprolite bed was worked in the mass of the Gault about 8 feet below that forming the base of the Chalk Marl; the washed heap of nodules contained fossils from both seams, but the species were all the same as those usually found in the Cambridge bed.

It is probable, therefore, that the erosion of local seams of nodules in the Gault contributed to the accumulation of the various kinds of nodules and fossils found at the base of the Chalk Marl.

From Reach the marl has been followed under the Fen, west of Burwell, towards Wicken, but this locality is not within the area described in this memoir.

Outliers.

The great number of outliers which occur to the westward of the main line of outcrop is remarkable, but the two circumstances which have contributed to their formation are not far to seek; the one is the fact we have had occasion to point out so frequently, the uneven surface of the Gault, for the hollows filled with Chalk Marl are of course left as outliers when the rest of the chalk has been removed; this will account for the number of small patches scattered

over the Gault area, from which the coprolites have been worked out under a varying thickness of Chalk Marl. The larger outliers owe their existence to the tongue-like projections of Boulder Clay, which, stretching eastwards from the main mass of the clay, have protected those portions of the Chalk which underlie them; the ridges previously mentioned (page 16) have thus been produced.

The first outlier in the S.W. corner of Sheet 51 occurs between Wendy and Whaddon; it occupies a long hollow or channel in the Gault, for though about three-quarters of a mile in length from S.W. to N.E., it makes no feature whatever on the ground; its maximum depth in the centre was about 12 feet, but the surface of the Gault was seen to be very irregular, and in one part between it and the Chalk was a small layer of ferruginous sand.

The next outlier occurs on the slope N.W. of King's Bridge, and must be some 30 feet above that spot where the nodule bed was found below the alluvial level of the river Rhee. Other outlying patches occur to the N.E., between Orwell and Barrington.

To the northward lies the long ridge which rises into the Orwell and Haslingfield hills; the coprolite bed has been followed all round these, and has been or is being extracted from all places where it lies within 20 feet of the surface. At Harston it has been dug close down to the river bed; this occurred, for instance, about half a mile S.S.W. of the church and it may possibly extend under the river here in a narrow neck so as to join on to the main mass about Hoffer Bridge.

The greater part of Barrington stands upon Gault, which rises up to form an irregular ridge hereabouts, but the church is built on a small outlier of Chalk Marl, and in 1875 the pits to the westward exposed the northern edge of the Gault ridge, which was seen "sticking up like a wall" along these workings, the fossil bed following it, and in places standing almost vertical. The foreman says that on the back or hill-side of these ridges, where they occur, is often found a second seam of fossils, separated from the lowermost by a foot or so of marl or marly clay.

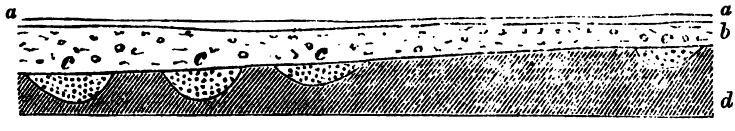
At another pit, three-quarters of a mile west of the church, they were working on the slope of a Gault ridge that pitched down at an angle of 30 or 40 degrees; according to the workmen this rolled over to the north where they had worked out the coprolites, and the layer containing these cropped out on each side; the Gault here was also full of slickensided surfaces.

One of the Coprolite pits on the south side of road, near Foxhole Down Farm, Orwell, showed a gradually increasing slope of Gault slightly undulating in the deeper parts, and broken into numerous irregular and steep-sided pockets where it rose within 2 feet of the surface.

This pocketty condition of the outcrop is very frequent where the seam rises at a low angle, and coprolites are always dug out of the holes; it does not seem to be in any way connected with the erosion of the Gault, but it is difficult to account for the phenomenon in a satisfactory manner. Mr. O. FISHER has figured an instance of this which he kindly allows us to reproduce, he attributes the hollows to the agency of ice, and without endorsing this opinion we admit that pressure of some kind seems to have come into action, for when the clay forming the sides and bottom of the pockets is lifted up with a spade it exhibits a platy structure with striated surfaces, greatly resembling slickensides.

Fig. 4.—Section in a Coprolite Pit, east of Harlton.

(For the use of this Fig. and Fig. 5, we are indebted to the kindness of the author and of the editor of the *Geological Magazine.*)



Scale, 12 feet to an inch.

a. b. Soil and gravelly earth. ("Warp and Trail" of Mr. OSMOND FISHER).

c. Pockets of phosphate nodules, 1–2 feet deep. *d.* Gault.

The coprolites have recently been dug all along the outcrop north of Wimpole; the surface of the Gault was seen to be often irregular, and the nature of the Greensand very argillaceous. A marked ridge of Gault runs up the small valley west of "Wimpole Ruins" at right angles to the direction of the ridge along the valley from "Wimpole Hole."

Pits near the latter place exhibited the following succession of beds:—

	Feet.
Boulder Clay - - - - - - - -	2
Grey Marl, with occasional lumps of hard clunch - -	4
Hard blocky clunch (with Marl between the lumps) - -	5
Coprolite bed - - - - - - - -	¾

The outcrop of the Marl in this neighbourhood is regulated by that of the outlying Boulder Clay, the presence of which has preserved it from denudation.

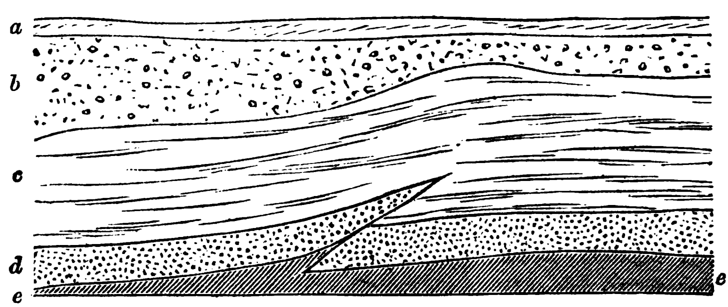
To the S.E. of Wimpole are two small outliers, one of the Marl and Coprolite bed; the other mere traces only of the latter, with Coprolites scattered on the surface.

Crossing the ridge to the northward the irregular outcrop of the Marl about Eversden may be noted.

At Harlton two marked indentations of the line will also be seen, one of these is caused by a ridge of Gault which was found running southwards through the field adjoining the Rectory garden.

Between Harlton and Haslingfield Mr. O. Fisher noticed several curious sections in the Coprolite pits open in 1871.* Fig. 5 is one of these, and shows a small slip or fault affecting the nodule bed, such slips are not uncommon; for a description of the other section, which is more complicated, we must refer the reader to the paper in the *Geological Magazine.*

Fig. 5.—Section in a Coprolite Pit between Harlton and Haslingfield.



Scale, 4 feet to an inch.

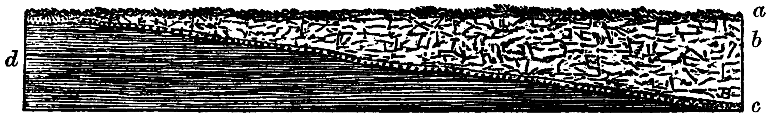
a, *b*. Soil and gravelly earth (Warp and Trail of Mr. Fisher).
c. Chalk Marl. *d*. Nodule bed. *e*. Gault.

At *Haslingfield* the church and the greater part of the village stands upon Chalk Marl, but a strip of Gault runs through the north end of the village, separating the mass of chalk on the south side from an outlier of considerable size, which occupies the ground to the northward, and from which the phosphate nodules have now been almost entirely extracted.

The outcrop of this outlier makes a well defined rise in the road leading to Cantalupe Farm, and barely a ¼ mile north of this point on the left side of the road there was a trench dug for coprolites in 1875, which was about 30 yards long, and had a depth of 20 feet at one end; the nodules were embedded in a very dark clayey marl, containing fewer glauconite grains than usual, and the seam was inclined at an angle of about 12°, rising up along the surface of the Gault till it cropped out under the soil.

* *Geol. Mag.* vol. viii. p. 68–70.

Fig. 6.—Section in a Coprolite Pit N.E. of Haslingfield.



Scale, about 40 feet to an inch.

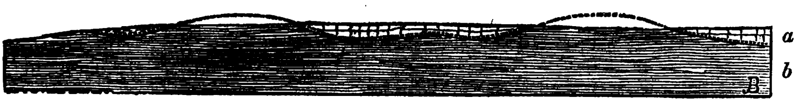
a. Soil. *b.* Chalk Marl. *c.* Nodule bed. *d.* Gault.

The result of this dip was to produce a long patch of "dead ground" extending across several fields to the west for the distance of half a mile; the average breadth of this was about 100 yards, and beyond this strip of clay the Greensand seam again came on and dipped northwards, but did not descend to such a depth as on the south side, the trenches dug to work it being only about 8 or 10 feet deep. Further north it appeared to rise again slightly, and approaching the surface extended over several acres of ground in a remarkably pocketty condition, the nodules being dug out of holes like those shown in Fig. 4.

In a field about a quarter of a mile S.E. of the above-mentioned section two other patches of "dead ground" were found to exist; at the time of our visit a trench was dug across the intervening hollow in a direction about N.E. by N., at the southern end of this the nodule bed cropped out under 3 feet of clayey soil, but sloping down rapidly northward it soon attained a depth of 22 feet, rising again irregularly it reached the surface at a distance of about 120 yards from the former outcrop. The Greensand seam was thickest in the deeper part of the hollow, the dark Glauconite Marl extending upwards fully 2 feet above the surface of the Gault, and the phosphate nodules being there accumulated to a depth of about 12 inches, while near the outcrop there were hardly any nodules in the Marl.

The following diagram shows the general relations of the Gault and Chalk Marl at this place, and explains the manner in which the spots of "dead ground" have been produced.

Fig. 7.—Diagram Section across the Field N.E. of Haslingfield.



Scale, horizontal and vertical, 300 feet to an inch.

The broken line shows the former continuation of the Coprolite bed.

a. Chalk Marl. *b.* Gault.

On the slope to the south the marl and coprolites occurred again in a shallow channel on the flank of the hill, which was not deeper than 5 or 6 feet, and the intervening ridge of Gault seemed to widen out towards the river, but it was not possible to find out the exact lie of the beds here, as such details can only be ascertained when the ground has been trenched for working the coprolites. Northwards, towards Cantalupe Farm, the depth of the works averaged about 20 feet.

In the neighbourhood of Grantchester there are two long outliers resting on the flanks of a Gault ridge, which comes to the surface along the higher ground between Grantchester and Barton, crossing the main road by the third milestone from Cambridge, as shown in Fig. 9. Just north of this point the nodule bed was seen cropping out under 4 feet of loamy soil, and dipping down to the north at an angle of 20°, for at about the distance of a chain it lay at the depth of 26 feet.

The outlier, of which this forms a part, stretches eastward to the river bank north of Grantchester, westward it is cut off from the mass underlying Barton Field by a narrow neck of Gault, and its northern boundary lies at a much

lower level than the southern, where it rests against the Gault ridge previously mentioned.

Fig. 8.—Section through Grantchester.

Horizontal scale, 3 inches to a mile; vertical scale, 200 feet to an inch.

a. Gravel. *b*. Chalk Marl. *c*. Gault.

In 1874–75 another small outlier of marl and coprolites was worked on the north side of Full Brook; these lay in a hollow, which was 20 feet deep in the centre near the road, but the surface of the Gault rose up rapidly towards the brook, forming a bank against which the Chalk Marl was bedded; the nodule seam appeared to thin out on approaching this, and passed into a few inches of sandy marl on the steep slope. The workmen stated that the seam averaged 9 to 12 inches in the hollows and not more than 6 inches on the ridges, and that sometimes it was absent altogether.

The nodule-bed has been worked all round the edge of the Marl bordering the Boulder Clay over Barton and Coton Fields, and a shallow outlying patch about three-quarters of a mile east of Coton was dug in 1873. The surface of the Gault here exposed was extremely uneven, and the Greensand was followed in and out of the various hollows, so that its boundary can only be shown by a very general line on the map.

In 1876 there were workings west of Whitwell Farm, which passed through a few feet of Boulder Clay before reaching Chalk Marl, and there must be a considerable area of the marl concealed by this clay to the northward and westward.

The Coton ridge was doubtless at one time continuous with that which runs from the Observatory to Castle Hill, from under which the coprolites have been dug out at a maximum depth of 24 feet; near the gaol they must be covered by about 30 feet of Chalk Marl, but the underlying Gault rises up to the northward and forms a ridge running through the Cemetery and across the road to Histon. Beyond this is another small outlier, from which coprolites have been obtained between the windmill and the farm to the N.E.; but the portion adjoining the road has not yet been worked so far as we can ascertain.

By the windmill, half a mile N.W. of Chesterton, a small patch of Chalk Marl occurs, from which the coprolites have been extracted, and extends from the top of the clay pits to the back of Rose Cottage, where it underlies the gravel.

To the north of Chesterton two other small outliers were found beneath the gravel, and the coprolites were all extracted from them in 1873.

In the preceding pages the uneven surface on which the Greensand rests has been the subject of frequent remark, and we have seen that the irregularities sometimes present the appearance of long undulations, and sometimes of local irregular ridges and hollows. Hitherto we have referred these inequalities to a single mode of origin, the action of current erosion; but it is at any rate possible that another cause may have co-operated in their production; the existence of small anticlinal and synclinal flexures, affecting both Gault and Chalk Marl alike, would give origin to similar appearances. It is accordingly desirable that we should inquire how far this latter cause may have assisted in producing the present aspect of the uneven surface.

Such small flexures have been observed to affect the higher parts of the Chakl, but they may or mav not extend downward so as to

affect its base also: the probability is, indeed, that some of them do; it will, for instance, be shown in the sequel that a shallow synclinal strikes through the Gog-Magog Hills from S.E. to N.W., and it is probable, therefore, that the depression of Coldham Common is only the continuation of this synclinal trough. It is also a fact that in this vicinity little difference was observed in the thickness of the nodule bed, while in those hollows which are clearly the result of erosion there is generally a greater accumulation of nodules; but the clay ridge near the Newmarket road had more the appearance of a "hogsback" or bank left by erosion.

We cannot, however, point to any other instance of a roll or ridge to which this hypothesis appears applicable. It might be thought that the low ridge running through Grantchester was a similar case; but its direction is nearly due E. and W., while that of all the folds observed in the Chalk is from S.E. to N.W.; again the Grantchester ridge is prolonged into an irregular hummock of Gault near Barton, the greatest width of which is from north to south. The surface here has evidently been modified by local erosion; consequently it must remain doubtful whether subsequent flexure has had anything to do with the formation of the ridge.

As regards the minor hollows and ridges so frequent in the S.W. portion of the area described, near Whaddon, Orwell, &c., there can be little doubt that they are the result of current erosion, as originally suggested; all the phenomena connected with them are only explicable on this supposition, and the mere fact that they exhibit no constancy whatever in the direction of their greater length is sufficient to negative the idea of their being in any way due to lines of flexure.

It is equally impossible to attribute the remarkably uneven surface of the Gault near Horningsey to any arrangement of anticlinals and synclinals. The greater depression appears to have its longer extension in a S.W. and N.E. direction, while the minor ridges are quite irregular, some being transverse to this, and others running nearly N. and S.

We conclude, therefore, that of the two causes assigned for the production of these inequalities in the surface of the Gault, that of subsequent flexure is seldom applicable, and that by far the greater proportion of cases are due to local erosion during the deposition of the Greensand itself.

Chalk Marl.

Zone of Rhynchonella Martini.

The beds composing the mass of the Chalk Marl vary somewhat in colour and texture, but are always more or less argillaceous. The few feet immediately overlying the nodule bed consist of a grey clayey marl, with a sprinkling of glauconite grains, which diminish in number upwards. The next 10 or 12 feet are often harder and more lumpy, sometimes bluish and sometimes greenish-grey; these

pass into softer greyish-white marl or clunch, above which are about 40 feet of similar grey or bluish argillaceous rock. The whole thickness is about 60 feet at Cherry Hinton near the line of section in the Plate, and it seems to preserve the same average thickness across the area shown in the map (Frontispiece), though it may thicken somewhat to the S.W.

The lower part of this Chalk Marl is well exhibited in the numerous coprolite pits, which are frequently between 20 and 30 feet deep; but the upper beds are not often exposed.

In describing the sections the same arrangement will be adopted as with those of the coprolite bed.

Main Mass.

The outcrop of the Chalk Marl enters Sheet 47 near Bassingbourn, and stretches to the N.E. between the boundary lines of the Cambridge Greensand and the Totternhoe Stone by Whaddon, Meldreth, and Shepreth. From hence to Cambridge its surface is much obscured by outspreads of river gravel. Eastward from Cambridge the Chalk Marl occupies a considerable area, Teversham, Ditton, Horningsey, Quy-cum-Stow, and Wilbraham Fen, Bottisham, Swaffham Bulbeck, and Long Meadow being all situate upon this lowermost zone of the Chalk. The more prominent portions of the ground, as those near Teversham and Bottisham, may be capped by small outliers of Totternhoe Stone, but in the absence of sections it is impossible to be certain of their existence.

The first exposure noted by us is the small clunch pit marked on the Ordnance map east of Shepreth; in this the nodular base of the Totternhoe Stone is shown with a few feet of the underlying Chalk Marl. There is nothing which can be called bedding in the latter, but it is curiously jointed, the lines of separation presenting in one place a concentric appearance. The material is rather tough than hard, and breaks with a curving marly fracture.

In the clunch pit on the north side of Hauxton Mill Bridge there is 12 or 15 feet of soft crumbling grey marl containing a few small Brachiopods and fragments of *Inoceramus*; the bottom of this pit is probably not more than 20 feet above the nodule bed, so that this is at a lower horizon than that at Shepreth.

The lowermost beds of the Chalk Marl, as seen in the coprolite pits at Trumpington, Coldham Common, and elsewhere, have already been described (see pp. 32, 36).

At the waterworks, on the road from Cambridge to Cherry Hinton, the large receiving well was originally dug down to a depth of 46 feet, and the beds passed through were as follows (see also p. 159):—

	Feet.
Soil and light-coloured clay	6
Dark clunch	23
Light-coloured clunch	7
Grey chalk	4
Blue "gault" (clunch)	6

The nodule bed of the "Cambridge Greensand" was found below, when the well was deepened in 1875, the surface of the true Gault being 48 feet from the top, so that the above is almost a complete vertical section through the Chalk Marl, for the thickness of the clunch between this spot and the outcrop of the Totternhoe Stone cannot be more than 10 or 12 feet. Bluish shaly marl is thrown out of the ditch between the waterworks and the well-head, which may belong to that termed "dark clunch" above.

A well near the cross-roads at Fen Ditton was sunk through 33 feet of Chalk Marl, and a strong spring was found in the nodule-bed at its base.

The softer and more clayey portions of the marl are sometimes dug and shaped into large bricks, which are dried in the sun and used in the construction of outhouses and other rough buildings; shallow pits whence such material has been obtained occur by the roadside half a mile south of Anglesey Abbey, and near the hamlet called Long-Meadow, west of Swaffham Bulbeck.

North of the last-mentioned village the greater part of the Chalk Marl is hidden under the black soil of Swaffham Fen, but its lower beds are shown in the coprolite pits, and its uppermost layers are found in the clunch pit two furlongs S.S.E. of Swaffham Abbey.

Its upper portion is again seen emerging from under the "brassel"* or Totternhoe Stone at the west corner of the large quarries near Reach (see p. 48), and the thickness exposed along the south-western face is about 30 feet; the mass of this is a greyish-white blocky clunch, rather hard when dry and breaking with a marly fracture; the bedding is indistinct, but the joints are strong and numerous; this clunch passes down into darker and softer brownish-grey marl and finally into bluish shaly marl, of which 3 or 4 feet are shown at the bottom of the quarry, these lower beds being full of fossils. At the cottages north of the quarries the wells are between 20 and 30 feet deep, so that the thickness of the Chalk Marl here must be about the same as at Cherry Hinton, or from 50 to 60 feet.

Similar firm Chalk Marl is to be seen underlying the Totternhoe Stone in the northern pit at Burwell (see p. 47).

Outliers.

There are only two outliers which contain any great mass of Chalk Marl; that between the valleys of the Rhee and Bourn, and that underlying the hills between Madingley and Barton; the former comprises the whole of the zone and much even of the overlying Grey Chalk intervenes between it and the capping of Boulder Clay; the latter too along its southern slopes in Barton Field must display almost the entire thickness of the Marl, but northward the base line of the Boulder Clay gradually descends and cuts out its upper beds, leaving little more than half its thickness under Coton Hill.

Most of the smaller outlying patches of the Chalk Marl have already been mentioned in describing the noduliferous layer which lies at their base. Good sections of the beds overlying this were seen in some of the coprolite pits and are noticed at pp. 32, 36; as however, the nodules have now been worked out from underneath nearly all these outliers, future excavations in them will only disclose the disturbed and broken-up materials which were thrown back into the trenches.

In the clunch pit three-quarters of a mile south-east of Kingston the following beds are seen :—

	Feet.
Rubbly chalk - - - -	5
Grey sandy chalk - - - -	1½
Rubbly chalk - - - -	3
Grey sandy chalk - - - -	1½
Hard blocky chalk or clunch, about -	10

The nodule bed lies below this, but is not seen on account of the talus; a tunnel was commenced here for working the coprolites, but so much water was met with that the undertaking was abandoned.

Another pit, half a mile W.S.W. of Harlton, shows about 20 feet of greyish marl or clunch, containing small Brachiopods and other fossils. The base of this must be 20 or 25 feet above the coprolite bed.

A clunch pit, south-eastward of Madingley, is cut through Boulder Clay to Chalk Marl, about 20 feet of the latter being shown with an irregular hard bed 2 or 3 feet thick near the top.

* We cannot answer for the spelling of this local term, ? allied to "brash, or to *brossil*," a name given to layers of hard rock in the Midland Counties.

LIST of FOSSILS from the CHALK MARL.

——	Kingston.	Harlton.	Madingley.	Hauxton Mill.	Swaffham.	Reach.	Burwell Victoria Quarry.
Lamna (tooth) - - -	...	...	...	...	...	...	×
Otodus appendiculatus, *Ag.* - -	×	..	...	...	×		
Ammonites varians, *Sby.* - -	...	...	...	×	×	×	
Inoceramus latus, var. Reachensis, *Ether.*	...	×	...	×	×	×	
Lima globosa, *Sby.* - - -	×	×	×	...	...	...	×
Ostrea vesicularis, *Lam.* - -	×	×	×	×	×	×	×
Pecten orbicularis, *Sby.* - -	...	...	×	×			
Plicatula inflata, *Sby.* - -	×	×	×	×	...	×	×
Kingena lima, *Defr.* - -	...	×	×	...	...	...	×
Rhynchonella grasiana, *D'Orb.* -	×	×	×	×	...	×	
„ Mantelliana, *Sby.* -	...	×	...	...	...	×	×
„ Martini, *Mant.* -	×	×	...	..	×	×	
Terebratula semiglobosa, *Sby.* -	×	×	×	...	...	×	×
„ biplicata, *Sby.* - -	...	...	×	×	...	...	×
Terebratulina gracilis, *Sby.* var. nodulosa, *Ether.*	...	...	...	...	×	×	...
„ striata, *Wahl.* - -	×	×	×	...	...	×	...
„ var. triangularis, *Ether.*	...	×	...	...	...	?	...
Cidaris dissimilis? (spines) - -	×	...	...	×			
Discoidea subucula, *Klein* - -	...	...	...	...	...	...	× ?
Holaster subglobcsus? *Leske* -	...	...	×				
Serpula annulata, *Reuss* - -	...	...	×	...	...	×	
Vermicularia umbonata, *Sby.* -	...	×					

CHAPTER V.—LOWER CHALK.—*continued.*

Grey Chalk.

The Totternhoe Stone.

Above the Chalk Marl, and generally forming the first rise in the escarpment of the Lower Chalk, there occurs a compact sandy chalk, which appears to be the representative of the well-known Totternhoe Stone. Like that rock it consists of a light greyish brown or buff sandy chalk, containing many organic remains and small scattered brownish phosphate nodules. Being a sandy and permeable bed, and resting as it does upon argillaceous marls below, it is naturally a water-bearing bed, and its outcrop may indeed be roughly traced by means of the strong springs thrown out at intervals from its base.

Mr. Whitaker has described the Totternhoe Stone in its course through Bucks, Beds, and Herts, and has traced it north-eastwards as far as Hitchin; he also observed it near Ashwell,* and from this locality we have traced it through Cambridgeshire as far as Burwell.

The stone has been largely quarried in many places for building material, and has been used in the construction of many of the old churches in Cambridgeshire; being easily cut and carved it serves excellently for interior mouldings, but unless the blocks are carefully chosen it is liable to weather and crumble away when used for exterior work.

Analysis of a Specimen of Totternhoe Stone from Burwell, by Dr. Frankland.

Composition in 100 parts.

Moisture, at 100 degrees	·66	
Alumina	·53	
Sesquioxide of iron (partly protoxide)	·68	
Calcic carbonate	85·91	
Magnesic carbonate, trace	—	
		87.78

Insoluble Residue (Clay).

Silica	8·5	
Alumina and protoxide of iron	{ ·32 1·19	
Lime	·28	
Magnesia	·29	
Organic matter	·44	
		11·02
		98·80

Main Mass.

The most easterly point where Mr. Whitaker has recorded the occurrence of Totternhoe Stone is at the spring-head of the river Rhee, east of Ashwell Church.† A similar spring-head, half a mile S.S.W. of Bassingbourn Church‡ in Sheet 47, is doubtless an indication of the same stone overlying the

* *Geological Survey Memoirs,* vol. iv. pp. 38–42 (1872).
† *Ibid.* p. 42.
‡ On the Ordnance map the watercourse is continued too far westward, the spring is at the point where it takes a sharp turn to the north.

Chalk Marl. From Bassingbourn it probably runs through Kneesworth along the edge of the rising ground south of Dyers Green. In 1816 Prof. HAILSTONE, speaking of the Burwell Stone, remarked "that in an extensive pit at Kneesworth, on the other side of the county, the same bed occurs again, where it preserves an uniform thickness and direction." *Trans. Geol. Soc.*, vol. iii., p. 249. A pit by the roadside, about three-quarters of a mile west of Melbourn Station, shows some 2 feet of lumpy clunch like that noted in many coprolite pits, but also seen elsewhere about the horizon of the Totternhoe Stone. Hard chalk occurs in the railway cutting N.E. of Melbourn Station, and may represent the Totternhoe Stone, but no good exposure of it is seen anywhere in this district.

The Totternhoe Stone probably enters Sheet 51 by the Old Paper Mills S.E. of Shepreth, and its basement beds are exposed in the clunch pit previously mentioned near that village (p. 40); above the Chalk Marl there is a layer of greenish nodules, similar to that which forms the base of the stone at Reach. Many of these nodules are covered with *Ostrea vesicularis*, and the following fossils were also found in and above this band,—*Holaster subglobosus, Plicatula inflata, Terebratula*, and *Ostrea normaniana?*

From this point the line is simply drawn to follow the natural features of the country, until it enters the railway cutting near Harston, where a hard Grey Chalk was passed through; the rock may be seen in the clunch pit S.W. of the station, and greatly resembles Totternhoe Stone, being hard, grey, sandy, and fossiliferous. From Harston the line is carried by contour to the "Well Head," south of Hauxton, which is doubtless thrown out at the base of this division; thence the line turns eastward and passes under the gravels of the Cam Valley.

The Totternhoe Stone must underlie Shelford, and it doubtless gives rise to the springs called the Nine Wells, three-quarters of a mile north of the railway junction, the hollow N.E. of this was once a marshy pool or mere, and the soil turned up by the plough is full of freshwater shells.

The feature made by the Totternhoe Stone may be traced across the fields beyond the Red-cross Toll-gate, and there are springs by the cottages north of Nether Hall.

In the large quarries near Cherry Hinton, just to the east of the line of section, the top of the Totternhoe Stone is touched and some depth of it was at one time worked for building-stone, now however not more than 4 or 5 feet can be seen at the bottom of the quarry; the stone passes upward into the whiter chalk above, but lower down it becomes darker and more sandy, according to the workmen. A well near the cottage is sunk to a depth of 20 feet, the water level being about 10 feet below the present bottom of the quarry, and as the springs are thrown out at the junction of the Totternhoe Stone with the Chalk Marl, this would give about 15 feet for the thickness of the former at Cherry Hinton.

The base of the Totternhoe Stone appears to be exposed in the railway cutting north of Fulbourn Asylum, 5 or 6 feet of blocky clunch being overlaid by a similar thickness of hard grey sandy stone, with a nodular bed at its base; at the east end the beds seem to be faulted downwards a few feet. The top of the stone is shown in the small clunch pit to the south of the line, forming a solid bed of grey sandy rock about 3 feet thick, and containing *Rhynchonella Mantelliana, Terebratula semiglobosa, Avicula gryphæoides*, and *Vermicularia umbonata*. The spring supplying the parish pump, called the Poor Well, at the western end of Fulbourn, is probably from the Totternhoe Stone. The connexion of this spring with the water level under the hills is shown by the fact that when it was dammed up in order to clear out the well, the water rose in the well at the Windmill on the hill to the S.W., and sank down again when the Poor Well was re-opened.

The boundary of the Totternhoe Stone then turns northward round the low hill which projects into Fulbourn Fen. The railway cutting shows about 12 feet of grey lumpy clunch, with pockets of hard yellow marl and gravel, this must be just above or in the top of the Totternhoe Stone, which seems in some places to put on a nodular character; the wells in the road near the railway station are about 10 to 12 feet deep, and their sides exhibit the nodular lumps of chalk, which are popularly called "chalk-stones;" the water used to over-

flow from these wells in the winter before Willbraham Fen had been drained to its present level.

At the springs called Shardelow's Well, E. of Fulbourn, the water bubbles up very freely, and forms the main supply of the Wilbraham River, the other branch coming from sources to the N.E. of Great Wilbraham. All these springs are probably from the base of the Totternhoe Stone, but it is impossible to trace the outcrop of this zone under the superficial deposits in this neighbourhood; it is most probable, however, that it runs out for some distance to the N.W. of Wilbraham, under the ridge of gravel which stretches in that direction, and that the line turns back along the opposite slope to Spring Hall, near Bottisham. The spring here is probably thrown out at the base of the Totternhoe Stone, and thence the boundary line turns northward to the Whiteland springs, which are doubtless on the same horizon.

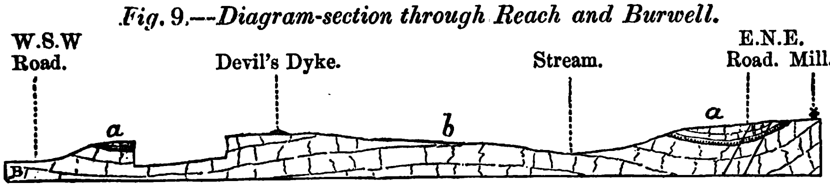
From this point a low ridge or scarp may be traced north-eastward through Swaffham Bulbeck and Swaffham Prior, forming the first rise from the Chalk Marl plain to the hilly country on the east. At the same time signs of disturbances or undulations in the level of the beds begin to appear; the outcrop of the Tottérnhoe Stone does not altogether correspond with this ridge, and in the pits near the windmill east of Swaffham Bulbeck the beds are seen to dip into the hill on each side; in the small clunch pit between the Swaffhams, where one would expect the Totternhoe Stone to be exposed, nothing like it is seen, and the beds shown appear to belong to the underlying Chalk Marl.

N.W. of this, and just before entering Swaffham Prior, the road traverses a curious hollow or combe, a strong spring used to issue from this, but the source was enclosed in 1870, and the watercourse through Mr. Allex's grounds has been dammed up to make a pond and rockery. It is probable that a slight synclinal in the Chalk is the cause of the abundant water-supply at this point, and the same appears to be the case at Cherry Hinton (see p. 130).

At the bottom of the clunch pit, a quarter mile N.E. of Swaffham Prior Church, there is a hard grey sandy stone exposed which much resembles Totternhoe Stone, containing small brown phosphate nodules and some fossils, such as *Rhynchonella Mantelliana, R. grasiana, Terebratula semiglobosa, Kingena lima*, and *Vermicularia umbonata*. The level of this bed is considerably above that of the spring above mentioned, and if it belongs to the upper part of the Totternhoe Stone this must be brought up by a rise in the beds or by a fault.

To the northward there is a disturbance which affects the boundary lines considerably, for there appear to be two anticlinal axes running from S.S.E. to N.N.W. and bringing up the Chalk Marl on each side of Burwell as shown in the section Fig. 9.

Fig. 9.—Diagram-section through Reach and Burwell.



Horizontal scale, 2 miles to an inch. Vertical scale, 200 feet to an inch.

a. Totternhoe Stone. *b.* Chalk Marl.

Under these circumstances it is difficult to trace the outcrop of the Totternhoe Stone with any accuracy between Swaffham Prior and Burwell. The southern portion of the latter is built upon a projecting tongue of the stone which appears to lie on the slope of a synclinal hollow. The stone crops out near the road leading S.E. from the High Town Windmill, and probably also at the base of the bank running north and south on the western side of the main street. Excellent sections are to be found in the numerous quarries to the east of this street.

Perhaps the best exposure of Totternhoe Stone is seen in that called Carter's

pit near the church, and where this has been recently worked near the stable the section is as follows:—

		Feet.
	Soil and chalk rubble - - - - -	4
	Thin bedded greyish white chalk - - -	10
Totternhoe Stone.	Course of hard brownish-grey stone projecting in the weathered face, and called "bond" by the workmen - - about	3
	Grey sandy stone in thick beds - seen for	10
		27

The whole of these beds are burnt for lime, and the "Burwell Stone," as it is sometimes called, is used for building purposes; its lower portion is only used for inside work, but the "bond" rock, if properly dried, becomes very hard and makes a good building stone. The foreman here stated that they had dug to a depth of 15 feet from the base of the bond rock, and were then stopped by the inflow of water. As elsewhere small brown phosphatic nodules are common in this upper part of the Totternhoe Stone, nodules of iron pyrites occur, and fossils are very numerous and well preserved (see list, p. 49). The Ammonites are chiefly found in the "bond," and also occur in the lowermost layers of the overlying Chalk. A similar section to the above is visible along the N.E. face of the same quarry.

In Mr. Davey's pit just to the south the "bond" rock does not weather out quite so distinctly; it is known, however, to the workmen by its distinctive characters, and is about 3 feet thick; the largest block known to have been obtained from it weighed five tons before it was dressed (a cubic foot of the stone being calculated to weigh one hundredweight). The blocks are shaped with a tool somewhat like a two-edged battleaxe, and are allowed to get thoroughly dry before they are used for building.

Another pit north of that first described showed the following succession:—

	Feet.
Soil and rubbly chalk - - - - - -	4
Chalk in thin layers - - - - - -	10
Tough grey sandy stone in thick bed with many fossils (Totternhoe Stone) - - - - - -	10

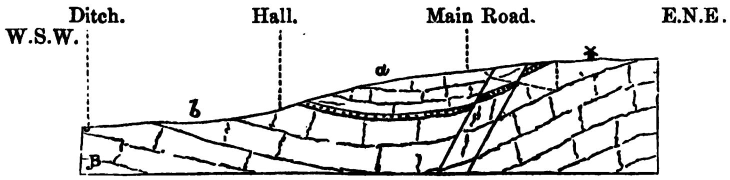
At the Victoria Quarry, between the Windmills at Burwell High Town, there is a very interesting section, the following beds being shown along the face recently worked (1878):—

		Feet.
Totternhoe Stone.	Hard grey sandy stone, in beds of some thickness, except near the surface, where it breaks into thin layers -	12
	A course of hard sandy stone, containing some iron-pyrites and full of hard brownish calcareo-phosphatic nodules, from the size of a pea to that of a potatoe, they are brown inside but many have a greenish exterior coating; fossils abundant - - - -	½ to 1
Chalk Marl.	Hard clunch, marly and blocky - about	15

None of these beds are used for building, and the nodule band is carted away as rubbish, for it will not burn into lime. The nodules are similar to those found at Reach, and described by Prof. HAILSTONE (see p. 48). A small fault traverses the pit from N.N.E. to S.S.W., throwing the beds down on the W. side about 3 feet. The dip of the nodule bed as seen along the north face is westward at about 3°, but its true direction appears to be to the W.S.W. The workmen stated that in sinking the well at the public-house

west of the pit the nodule bed was pierced at a depth of 22 feet, thence it rises to the E.N.E. till near the lime kiln it is only 5 feet from the surface, and it was said to have cropped out near the pathway leading into the quarry. The whole of the eastern face, which is not now worked, must therefore belong to the underlying Chalk Marl, about 20 feet of this being seen.

Fig. 10.—*Diagram-section through Victoria Pit, Burwell.*



Horizontal scale, 4 inches to a mile. Vertical scale, 100 feet to an inch.

a. Totternhoe Stone, with nodule bed at base. *b.* Chalk Marl.

We were told that the well at the windmill to the east was 60 feet deep, this therefore must pierce nearly the whole thickness of the Chalk Marl, and the water-supply is probably obtained just above the "Cambridge Greensand."

Nothing like Totternhoe Stone is to be found in the old quarry belonging to Mr. Stephens, N.W. of the Windmill, the whole exposed face of which consists of firm blocky greyish-white clunch for about 30 feet, but the fragments thrown out of the deeper holes were bluish and shaly; near the top of the northern face are indications of a marly band having a slight apparent dip to the westward, but this is cut off by a fault at the N.E. corner. The whole section is very like that in the Reach Quarries (p. 48), and is probably in Chalk Marl.

As far as can be ascertained it seems likely that the beds quickly become horizontal, then resume their normal easterly dip, and the Totternhoe Stone probably takes the ground again to the east of High Town, and the spring in the hollow, a mile E.N.E. of Burwell Church, is doubtless an indication of its outcrop, but beyond this point it has has not yet been traced.

Outliers.

The Totternhoe Stone is exposed at several points in the long outlier which stretches westward from Haslingfield. In the old quarries south of that village the stone is hidden under talus, but it is seen in the newer quarry by the roadside a quarter of a mile south of the church; the lower part of this exposes several feet of thick bedded sandy stone, of a greyish brown hue, containing small brown phosphatic nodules, many specimens of *Rhynchonella Mantelliana,* and other fossils (see p. 49).

In the clunch pit south of Harlton similar beds of grey sandy chalk are shown, overlaid by thinner beds of a lighter colour, less sandy and with fewer fossils.

As the underlying marl is found in the clunch pit near the Wheatsheaf Inn, the outcrop of the Totternhoe Stone must pass above this and curve round toward the Eversden Quarry three-quarters of a mile westward; it would appear, however, to pass below this quarry, for the chalk here exposed, though somewhat like Totternhoe Stone, is not so hard or sandy, and seems to belong to a slightly higher horizon.

The large quarry above Orwell, some 20 feet deep, shows rather hard grey chalk in beds of varying thickness with phosphatic nodules and other organic remains; it is thrown down westward by a set of small faults. The thicker beds probably represent the Totternhoe Stone. Similar beds with phosphatic

nodules occur also in the pit about a mile east of the above, and thence the line of outcrop has been drawn to follow the contour of the hill back to Haslingfield.

It is quite possible that several outliers of Totternhoe Stone may occur over the undulating ground N.E. of Cambridge by Teversham, Quy, and Bottisham, but sectional evidence is wanting. The large clunch pits near Reach, however, disclose the existence of a small outlier resting on the south-western slope of the hill.

The eastern corner of these quarries has been recently worked, and the following section was observed in 1878:—

	Feet.
Hard grey sandy rock in definite beds, its basement-bed being very hard and containing many hard green-coated nodules, the whole called "brassel" by the workmen - - - - - -	6–10
Blocky clunch, of a lighter colour, less hard and more marly than the rock above, bedding indistinct - - - - - - -	4

The dip taken by the nodule bed is apparently about 7° to the W.S.W. The remarkable layer of phosphatic nodules, by which the base of the Totternhoe Stone is so well marked both here and at Burwell, was first noticed by Professor HAILSTONE in 1816, and is thus described by him:—

"In one of the pits at Reach a bed of clunch occurs which differs from the ordinary sort, and presents some remarkable appearances; the mass itself is much harder and is stuck full of concretions of a yellow indurated marl; outwardly they are of a green colour arising from the oxide of iron; they are in general kidney-shaped and of all sizes, from a hazel nut to an ordinary potatoe. The shape of the bed also deserves notice; its general thickness is about 15 inches, which it preserves for near 30 yards, as appears in the section of the quarry; it then diminishes at each end to a thin edge and at length totally disappears."*

These last words would rather seem to imply the thinning out of a lenticular bed, but the section then open may have so cut into the Totternhoe Stone as to show it thinning out upwards on either hand, as the dip brought its base to the surface. One face is still left, along which it rises eastward, and can be traced to within about 2 feet of the surface, and the clunch which emerges from beneath contains two bands of rubbly marl, rising slightly eastward (along the S.W. face of the quarry) and then becoming nearly horizontal, below these are about 30 feet of greyish blocky clunch with bluish shaly beds at the base which appear to keep nearly horizontal throughout the rest of the quarry.

The "brassel," as the hard basement layers of the Totternhoe Stone are here called, is only quarried to be carted into the Fens for road-metal, for it does not burn to a good lime.

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* *Trans. Geol. Soc.*, vol. iii. pp. 248, 249. He also states that the same bed occurs again at Kneesworth, "where it preserves an uniform thickness and direction."

FOSSILS from the TOTTERNHOE STONE.

—	Harlton and Haslingfield.	Orwell.	Cherry Hinton.	Fulbourn Cutting.	Burwell, 3 quarries.
Beryx (fragment)	...	...	×		
Dercetis (? Terebella)	...	...	...	...	×
Lamna (fragment)	×	...	×		
Otodus appendiculatus, *Ag.*	...	...	×	...	×
Ammonites Lewesiensis ?, *Mant.*	...	...	...	...	×
„ rhotomagensis, *Brong.*	...	×	...	...	×
„ var. Cenomanensis, *D'Arch.*	...	...	...	...	×
Belemnites plena, var. *Blainv.*	...	...	...	...	×
Nautilus elegans, *Sby.*	...	...	...	...	×
Avicula gryphæoides, *Sby.*	...	...	...	×	×
Inoceramus latus, *Mant.*, var. Reachensis, *Ether.*	...	× ?	...	...	×
Lima aspera, *Mant.*	...	...	...	...	×
„ echinata, *Ether.*	...	...	×	×	×
„ globosa, *Sby.*	×	×	×	×	×
Ostrea acutirostris, *Nilss.*	...	...	...	...	×
„ curvirostris, var. inflexa, *Ether.*	×	×	...	...	×
„ (Exogyra) haliotoidea, *Sby.*	...	...	...	...	×
„ vesicularis, *Lam.*	×	×	×	×	×
Pecten fissicosta, *Ether.*	...	×	×	...	×
„ orbicularis, *Sby.*	×	×	×	×	×
„ quinquecostatus, *Sby.*	...	...	...	...	×
„ Beaveri, *Sby.*	...	...	...	...	×
Plicatula inflata, *Sby.*	×	×	×	×	×
Spondylus striatus, *Sby.*	...	...	...	...	×
Teredo amphisbæna, *Goldf.*	...	...	...	...	×
Rhynchonella grasiana, *D'Orb.*	×	...	...	...	×
„ Mantelliana, *Sby.*	×	×	×	×	×
„ Martini, *Mant.*	×	×	...	...	×
Terebratula biplicata, *Sby.*	...	...	...	...	×
„ semiglobosa, *Sby.*	×	×	×	×	×
„ squamosa, *Mant.*	×	...	...	...	×
Terebratulina gracilis, var. nodulosa, *Ether.*	×	...	×	×	×
„ striata, *Wahl.*	...	×	...	...	×
Kingena lima, *Defr.*	×	×	×	×	×
Cidaris dissimilis ? (spine) *Forbes*	×				
Cyphosoma, ? or Pseudodiadema	...	...	...	...	×
Discoidea subucula, *Klein*	...	...	...	...	×
Holaster subglobosus, *Leske* (Shepreth)					
Cœlosmilia ?	...	...	...	...	×
Micrabacia coronula, *Goldf.*	...	...	...	...	×
Onchotrochus serpentinus, *Duncan*	...	...	...	×	
Serpula antiquata, *Sby.*	...	...	×	...	×
Vermicularia umbonata, *Sby.*	×	×	×	×	×

SUPPLEMENTARY LIST of FOSSILS from BURWELL in the WOODWARDIAN MUSEUM, CAMBRIDGE.

Corax, *Ag.*
Notidanus, *Ag.*
Ptychodus, *Ag.*

Ammonites Mantelli, var., *Sby.*
„ navicularis, *Mant.*
„ varians, *Sby.*
„ var. Coupei, *Brong.*
Nautilus Deslongchampsianus, *D'Orb.*
„ pseudoelegans, *D'Orb.*
„ reflectus (*Seely*, M.S.)
Scaphites æqualis, *Sby.*
Turrilites costatus, *Lam.*
„ Scheuchzerianus, *Bosc.*
„ tuberculatus. *Bosc.*
Trigonellites.

Aporrhais, sp.
Cerithium ornatissimum, *Desh.*
Dentalium majus, *Gardn.*
Pleurotomaria (several sp.)
Scalaria fasciata, *Ether.*
Solarium dentatum ?, *Desh.*
Trochus, sp.
Turbo, sp.

Anomia, papyracea, *D'Orb*, var. Burwellensis.
Avicula dubia, *Ether.*
„ filata, *Ether.*
Inoceramus striatus, *Mant.*
„ convexus, *Ether.*
„ var. quadrata, *Ether.*
Ostrea frons, *Park.*
Pecten elongatus ? *Lam.*
Pholadomya decussata, *Phil.*
Pinna tegulata, *Ether.*

Enoploclytia brevimana, *M'Coy.*
„ Imajei, *Mant.*
Glyphæa cretacea, *M'Coy.*
Necrocarcinus Woodwardi, *Bell* (Cherry Hinton).
Pollicipes glaber, *Rom.*
Serpula rustica, *Sby.*

Hemiaster Morrisii, *Forbes.*
Pentacrinus Fittoni, *Aust.*
Pseudodiadema, sp.

Zone of Holaster subglobosus.

This zone comprises the entire thickness of the Chalk between the Totternhoe Stone and the Melbourn Rock; the whole of it is shown in the large quarries near Cherry Hinton (close to the line of section, Pl. 6), and parts of it are seen in many other quarries along the escarpment of the Lower Chalk. There is indeed a greater number of exposures in this division than in any other portion of the Chalk of equal thickness, the reason probably being that the beds of this zone afford the best material for making lime.

Mr. WHITAKER speaks of similar chalk in Buckinghamshire as coming on above the Totternhoe Stone, and describes it as breaking up "into large irregular-shaped blocks with more or less curved surfaces;"* in another place he calls it "marly chalk breaking "irregularly so as not to show bedding."† The Cherry Hinton chalk might be described in the same terms, and it occurs with the same general characters throughout Cambridgeshire.

In accordance with the plan proposed at p. 22 we commence by describing the outcrop near the line of section (Pl. 6), and will then trace the zone first to the south-west and secondly to the north-east from that line.

At Cherry Hinton there is not any very marked line of separation between this zone and the underlying Totternhoe Stone, and two small slips or faults help

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* *Quart. Journ. Geol. Soc.*, vol. xxi. p. 400.
† *Mem. Geol. Survey*, vol. iv. p. 44. (1872.)

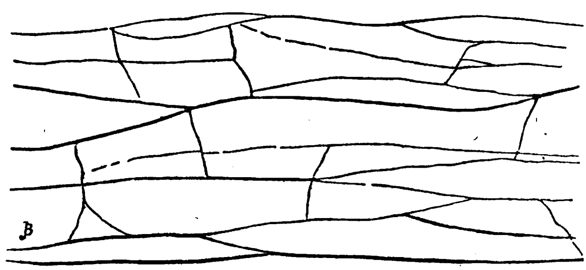
to obscure the junction; but 3 or 4 feet from the bottom of the quarry the rock comes away in smaller blocks, which are of a lighter colour, less sandy, and less fossiliferous.

The weathered western face exhibits this greyish-white chalk, and here the remarkable irregularity of its bedding is well shown; this appears to be characteristic of the whole zone, and has been called false-bedding, but it is not exactly analogous to the cross-stratification so often seen in sands and gravels, for, so far as our observation extends, the layers are not cut off abruptly, but thin out more or less rapidly in a lenticular fashion. It is a matter of some doubt whether this structure can be termed bedding in the true sense of the word. We question whether it is any proof of current action, and would suggest that the curved surfaces may be due to the contraction of a homogeneous mass in the absence of any definite bedding planes. We believe, in fact, that they are lines of jointing rather than of bedding.

That part of the pit which was chiefly worked in 1875–76 exhibited rather hard yellowish rock near the bottom (which must have been some 15 or 20 feet above the lowermost level of the quarry) with fossils in some abundance, especially *Holaster subglobosus, Plicatula inflata,* and *Terebratula semiglobosa,* and passing up into more marly cream-coloured chalk, the whole face being about 25 feet high.

In the upper part of the quarry at the southern corner was a freshly cut face of thick-bedded cream-coloured chalk, the apparent bedding being so irregular and lenticular that no dip could be taken. Fig. 11 shows the lower 10 or 12 feet of this face. (Compare Quart. Journ. Geol. Soc., vol. xvii. p. 291.)

Fig. 11. *Sketch of Divisional Lines in Chalk, Cherry Hinton Quarry.*



The uppermost layers of this chalk are almost white when dry, and contain very few fossils, *Ostreæ* and *Exogyræ* being the most common; the height from the middle stage of the quarry to the band of yellowish rock and marl just below the road at the top of the pit is about 40 feet.

To the southward this zone occupies the ground traversed by Wort's Causeway and the Hills Road, and is exposed in the quarry called Shelford lime-kiln on the Ordnance map. The beds are greyish or creamy-white in colour, and average from 1 to 2 feet thick, but as at Cherry Hinton they often thicken out lenticularly from a few inches to 3 or 4 feet. The cliff near the entrance is 30 feet high, and from this level to the bottom of the pit is about 15 feet; the lowest beds seen are not very hard, but yellowish and gritty. Fossils are frequent here; we obtained a tooth of *Polyptychodon, Holaster subglobosus,* and teeth of *Ptychodus, Lamna,* and *Otodus;* many others were subsequently collected by Mr. Allen (see p. 54).

The upper part of this zone is again seen in the Shelford clunch-pit on Steeple Hill, from 20 to 30 feet being shown in the lower part of this quarry; the chalk is greyish and rather soft, lenticularly bedded and much jointed; fossils are fairly abundant. (See list on p. 54).

From this point the grey chalk occupies the flank of the hilly ground N.W. of Shelford, and runs up the valley for some distance beyond Stapleford, but is not exposed in any quarries.

Passing under the gravels, which are spread over "Howe Field" and the parish of Little Shelford, it emerges to the west of that village, and sweeps round the hill-side between "The Well Head" and "Maggots Mount." Its upper beds are exposed in the quarries near the Obelisk on this hill, and are similar to those in the clunch pit near Shelford; the section here is given on p. 56.

Newton clunch pit, half a mile to the S.W., would appear to be in the upper part of this zone, it exhibits about 12 feet of hard whitish chalk with imperfect horizontal bedding; the beds are about 3 feet thick and split up into blocks of varying size and hardness; there are a few nodules of iron pyrites; *Holaster subglobosus*, *Terebratula semiglobosa*, *Kingena lima*, *Plicatula inflata*, and *Ostrea vesicularis* were the only fossils obtained.

The chalk of this zone forms the mass of the hills about Newton and Foxton, the highest levels only being capped by outliers of the Melbourn Rock.

The lower of the two pits S.E. of Foxton shows about 15 feet of rather soft blocky clunch, the lines of division being very irregular and sometimes nearly concentric; a discontinuous layer of rubbly marl was observed in one part of the pit, and iron pyrites nodules are abundant, some preserving their radiating crystalline structure, others decomposed into balls of brown earth. The lowest evel is about 30 feet below the base of the Melbourn Marl seen in the higher pit, and described at p. .

At Melbourn from 20 to 30 feet of the same chalk are to be seen in the pits south of the village, where it is largely burnt for lime; it comes away in large blocks and is here rather whiter than usual, but the joint planes are stained of a yellowish-grey colour.

We now return to the neighbourhood of Cherry Hinton, and proceed to trace the zone along the country northward of the line of section.

The lime kilns marked on the map, just south of where the roads meet at Cherry Hinton, are now disused, and the section is partly grown over; but it must at one time have exposed the lower part of this chalk and the Totternhoe Stone.

Eastwards this division occupies the lower slopes of the hills towards Fulbourn, and the base is again shown in the clunch pit near Fulbourn Asylum. The well at the asylum is just short of 60 feet deep; the whole of the hill therefore on which it stands is composed of the same chalk based upon Totternhoe Stone.

The steep slopes which descend towards the village of Fulbourn from the level of the windmill, five furlongs westward of the church, are also made by the outcrop of this zone, as, too, is the high ground which forms the south-eastern boundary of Fulbourn Fen; just south of Shardelows Well are some old workings, but these are now quite overgrown. The Fen itself is based upon the Chalk Marl and Totternhoe Stone, and the undulating ground which extends eastwards and northwards towards Great Wilbraham must be occupied by the zone of *Holaster subglobosus*, but no good sections are to be found.

Between Wilbraham and Bottisham a long ridge of gravel stretches out to the N.E., and has preserved these beds from destruction, so that they and the Totternhoe Stone underlie the gravel for some distance, but their outcrop is cut back along the Newmarket Road as far as Spring Hall. Thence they turn northward and skirt the eastern side of Bottisham Fen towards Swaffham Bulbeck. Here the zone of *Holaster subglobosus* is well shown in two pits east of the village; in that facing west, just below the windmill, hard greyish chalk is seen containing many decomposed nodules of iron pyrites; fossils seemed to be scarce, but the characteristic *Holaster* was found. The Melbourn Rock has recently been disclosed by a fresh excavation in the upper level of this pit (see p. 59).

The uppermost beds are again seen in the new pit which faces the north on the top of the hill; *Holaster subglobosus*, *Terebratula semiglobosa*, *Plicatula inflata*,

and *Ostrea vesicularis* occur here; about 15 feet are shown along the eastern face, overlaid by a course of yellowish nodular chalk, which dips to the W.S.W.; about 10 feet of hard white chalk intervene between this and the Melbourn rock above (see p. 59).

At Swaffham Prior, a quarter of a mile N.E. of the church is a small pit showing 15 or 16 feet of whitish irregularly bedded chalk, much shattered in one place, as if by small faults or slips; there appears, indeed, to be a considerable uplift here, for the basement bed is probably Totternhoe Stone (see p. 45); the upper beds will therefore belong to the lower part of the overlying zone; they contain *Holaster subglobosus, Ostrea vesicularis,* and a few other fossils.

From this point the outcrop widens out and occupies the country which is crossed by the Devil's Ditch as far as Ditch Farm. The base is seen capping the Totternhoe Stone in the quarries at Burwell, where it contains *Terebratula biplicata, T. semiglobosa, T. squammosa, Kingena lima, Rhynchonella Mantelliana, Pecten orbicularis,* &c.; thence it stretches south-eastward toward Exning and Newmarket.

Outliers.

The Grey Chalk forms a long narrow outlier averaging less than three-quarters of a mile in width between Barrington and Orwell on the south, and Haslingfield, Harlton, and Eversden on the north.

We have already noticed the quarries along the flanks of these hills in which the Totternhoe Stone is exposed, and in which some portion of the overlying clunch is also seen; there are, however, three pits which seem to be entirely above the horizon of the Totternhoe Stone.

The first of these is named Barrington Clunch Pit on the map, and is in hard greyish chalk with very few fossils, which cannot be very far up in the zone of *Holaster subglobosus,* but the only organic remains found in it, *Terebratula semiglobosa* and *Ostrea vesicularis,* do not give any indication of its exact horizon.

The next is a small quarry by the roadside a quarter of a mile S.S.E. of Orwell Maypole, which must be nearly 100 feet above the base of the Chalk Marl, and a hard greyish-white stone exposed in the lower part has yielded the fossils named in the list at p. 54.

Half a mile north of the last-mentioned pit is a much larger one called Eversden Quarry, the base of which appears to be between 70 and 80 feet above the coprolite bed, for the well at the cottage has a depth of 72 feet, and is probably sunk down to the base of the marl. The section is as follows (the fossils found being noted in the list below):—

Boulder Clay, 3 feet.
Rubbly Chalk, 2 or 3 feet.
Hard grey chalk in irregular blocks, some of large size, the lines of jointing frequently curved, and in some places slickensided, here and there presenting a concretionary structure; has somewhat the appearance of having been crumpled or disturbed; contains many decomposed lumps of iron pyrites, and seems to dip slightly down the hill to the north, 12 feet.

The hard chalk or clunch exposed in the last two pits is probably the same as that noted in the Cherry Hinton Quarry, and its horizon there must also be about 80 feet from the Gault; there would appear, therefore, to be a tolerably constant bed of hard rock about this level, but its characters are by no means so well defined as the Totternhoe Stone below.

The highest beds, therefore, in the outlier just described are in the zone of *Holaster subglobosus,* and nowhere reach the horizon of the Melbourn Rock.

FOSSILS from the ZONE of HOLASTER SUBGLOBOSUS.

—	Shelford, New Clunch Pits.	Shelford Lime Kiln.	Cherry Hinton.	Eversden.	Pit N.N.E. of Orwell.
Beryx sp. (opercular bones) - - -	...	×	×		
Otodus appendiculatus, *Ag.* - - -	×	×	×		
Oxyrhina Mantelli, *Ag.* - - -	×	...	×		
Odontaspis gracilis, *Pict. and Camp* -	...	×			
Ptychodus decurrens, *Ag.* - - -	...	×			
Fish vertebræ and coprolites - - -	×	...	×		
Polyptychodon interruptus, *Owen* - -	...	×	×		
Ammonites rhotomagensis, *Brong.* - -	×	×	×		
„ varians, *Sby.* - - -	...	...	...	...	×
„ var. Coupei, *Brong.* - -	...	...	...	...	×
Scaphites, sp.? - - - -	...	...	...	...	×
Avicula gryphæoides, *Sby.* - - -	...	...	...	×	
Exogyra haliotoidea, *Sby.* - - -	...	×	×		
Inoceramus mytiloides, *Mant.* - -	×	×	...	×	×
Lima globosa, *Sby.* - - - -	...	×	×	×	
Ostrea normaniana, *D'Orb.* -	...	...	×		
„ rauliniana, *D'Orb.* - - -	...	...	×		
„ vesicularis, *Lam.* - - -	×	×	×	...	×
Pecten Beaveri, *Sby.* - - -	×	×	×		
„ orbicularis, *Sby.* - - -	...	...	×	×	
„ quinquecostatus, *Sby.* - -	...	...	...	...	×
Plicatula inflata, *Sby.* - - -	×	×	×	...	×
Spondylus æquicostatus, *Ether.* - -	...	×	×		
Teredo amphisbæna, *Goldf.* - - -	...	...	×		
Kingena lima, *Defr.* - - - -	...	...	×	×	
Rhynchonella mantelliana, *Sby.* - -	...	...	×	×	×
„ Martini, *Mant.* - -	...	...	...	...	×
Terebratula biplicata, *Sby.* - - -	...	...	...	×	×
„ semiglobosa, *Sby.* - -	×	×	×	×	×
„ sulcifera, *Morris* - -	...	×	×		
Terebratulina striata, *Wahl.* - - -	...	...	×	×	×
Cidaris Bowerbankii, *Forbes* - - -	...	...	×		
„ dissimilis, *Forbes* (spines) - -	...	×	×	×	
„ hirudo, *Sorig.* - - -	...	×			
Discoidea cylindrica, *Lam.* - - -	...	×	×		
Goniaster (plate of) - - - -	...	...	...	...	×
Holaster lævis, var. trecensis, *Leym.* - -	×	×			
„ subglobosus, *Leske* - - -	×	×	×		
Enoploclytia sp. - - - -	...	×	×		
Serpula sp. - - - - - -	...	×	...	...	×
Pollicipes - - - - - -	...	×			

Remains of the following reptiles have also been found in this zone at the Cherry Hinton quarries :—*Ichthyosaurus campylodon*, Carter, *Polyptychodon interruptus*, Owen, *Pterodactylus sp.*, and *Saurospondylus dissimilis*, Seeley.

CHAPTER VI.—MIDDLE AND UPPER CHALK.

MIDDLE CHALK.

Melbourn Rock.

The division to which we have given the above name consists of several thin beds of yellowish laminated chalk with layers of marl, separated by courses of hard rocky chalk, the whole having a maximum thickness of 10 feet. These beds are generally to be found capping the escarpment of the Lower Chalk, or forming the base of the next rise intervening between it and the Upper Chalk 'scarp.

We have already had occasion to mention the band of yellowish marl which occurs near the top of the Cherry Hinton quarry; Dr. Barrois, in 1875, was the first to identify this as representing the horizon of his *Belemnites plenus* zone, and the subsequent detection of it in other chalk-pits, has greatly assisted us in tracing the zones which lie above and below. The best exposures of this rocky chalk occur near Melbourn and Harston, and the following is an analysis of a specimen from the latter locality.

Analysis of a Specimen of Melbourn Rock, from Maggot's Mount, near Harston, Cambridgeshire, by Dr. Frankland, F.R.S.

Insoluble residue on dissolving in acid -	·92
Silica - - - - - - -	6·44
Sesquioxide of iron and alumina - -	1·51
Calcic carbonate - - - -	87·66
Magnesic carbonate - - - -	3·44
Chloride of sodium - - - -	·36
Phosphoric anhydride (P_2O_5) - - -	·18
	100·51

At Cherry Hinton a narrow band of yellowish gritty laminated marl is seen in the southern corner, and is let down to the north by a fault with a throw of 4 or 5 feet, two sets of slickensides being shown with about 4 feet of crushed and disturbed chalk between. This is the basement-bed of the Melbourn rock, it is not very fossiliferous here, but *Belemnites plenus* and *Ostrea Naumanni* were obtained by Dr. Barrois, and Mr. Allen afterwards found a good specimen of the Belemnite in the chalk just below the yellow layer. The height of its outcrop is about 140 feet above Ordnance datum. The boundary line sweeps round the hill above Nether Hall and into the combe north of Wort's Causeway; thence it turns southwards and crosses the Causeway about a quarter of a mile north-west of the tumulus. A small pit has been opened here at the north end of the plantation, and the following beds are exposed:—

	Feet.
Chalky soil and rubble - - - -	4
Hard chalk with cream-coloured nodules -	2
Two courses of yellowish sandy marl, separated by a thin layer of hard chalk - -	1½
Hard cream-coloured chalk, with *Belemnites plenus* - - - - - -	3

All these beds probably belong to the zone characterised by *Belemnites plenus*, they dip 3° between S.E. and E.S.E.

The feature made by the outcrop of these beds continues to run nearly due south, and passes above the Shelford lime-kiln on the Hills Road, thence it bends westward and sweeps round the hills above Shelford. Steeple Hill is capped by an outlier of this division, and a complete section of the series of alternating layers of marl and limestone composing the Melbourn Rock is shown in the upper level of the Clunch Pit; this section was as follows in 1875, but it has since been cut back considerably.

		Feet.
	Loose chalk, with pockets of coarse gravel - - -	6
Melbourn Rock.	Hard chalk, with wide vertical joints - -	4
	Band of laminated buff-coloured marl, *Rhynchonella Cuvieri* - - - - -	1
	Hard bedded chalk, much broken by joints; *Lamna* (tooth), *Ostrea vesicularis*, *Rhynchonella Cuvieri ? Rh. plicatilis*, and a small quartz pebble were found in this bed -	3
	Softer laminated chalk with marly layers -	2
	Blocky white chalk, *Holaster lævis* (var. *trecensis*), *Ostrea vesicularis*, and *Terebratula semiglobosa* - - -	5
		21

The occurrence of the small quartz pebble (which was about an inch long) is remarkable, and recalls the existence of similar stones in the Cambridge Greensand. The workmen stated that small "cup-bones" (? fish vertebræ) had been found in one of the marl bands. These bands consist of gritty laminated marl, in which many lumps and nodules of chalk are dispersed, and would seem to indicate an interruption of the quiet conditions which prevailed during the deposition of the beds below.

There appears to be a second small outlier between Steeple Hill and the main outcrop, but no section is now open. The marl has not yet been observed anywhere near Stapleford, and the line on the map has been drawn in accordance with the general contour of the country and the calculated dip of the beds.

The hilly ground which rises up from Dale Moor, north of Sawston, probably owes its existence to the outcrop of this group of beds, but no exposures were noticed. Neither is there any sectional evidence for the line by Whittlesford and Stanmoor Hall, further than the fact that the chalk seen in the pit near the latter place resembles the overlying rather than the underlying beds; the springs also near Triplow are doubtless thrown out at this horizon.

Although sections along the main outcrop are thus few and far between, there are several outliers capping the hills which rise to the N.W., and in these there are many clunch pits, some of which exhibit sections of the Melbourn Rock. Thus in the pit near the Obelisk on Maggots Mount, the succession shown in Fig. 12 was measured at the eastern end. The height of the outcrop above datum here is about 150 feet.

Fig. 12.—Section in Chalk Pit W. of the Obelisk near Harston.

Scale, 40 feet to an inch. × × = Faults.

		Feet.
	a. Chalky soil and broken rubbly chalk - -	6 to 8
Melbourn Rock.	*b.* Hard bedded greyish chalk, ringing under the hammer - - -	2 to 3
	c. Buff-coloured chalk, rather soft, in two or three layers, with marly partings; *Belemnites plenus* and *Rhynchonella* - - - - -	3 to 2
	d. Hard greyish-white chalk, rocky and nodular - - - - -	1½ to 2
	e. Softer grey chalk, with yellowish stripes, resting in places on a thin layer of marl - - - -	1
	f. Rather hard cream-coloured chalk, irregularly bedded - - - - - - -	4

These beds appear to dip into the hill on each side, but the dip is increased at the western end by two small faults, which have let down the beds 3 or 4 feet on the east side. From 15 to 20 feet of nearly white or cream-coloured chalk, belonging to the zone of *Holaster subglobosus*, are shown in the lower part of the pit, and are burnt for lime.

The shape of Red-land Hill between Harston and Newton is probably due to a capping of beds similar to those above described; the steep slope on the NW. side has been artificially terraced.

Foxton Hill is capped in a similar manner, and the following section is shown in the higher of the two clunch pits, the beds being nearly horizontal:—

			Feet.
	Loose rubble and thin bedded chalk with traces of marly bands	about	6
Melbourn Rock.	Hard creamy-grey chalk	,,	3
	Soft yellowish laminated chalk with some nodules	,,	1½
	Harder cream-coloured chalk, with enclosed nodules of same colour	,,	1½
	Soft grey marl, with yellowish nodules	,,	¼
	Hard grey chalk, in beds about 6 inches thick, and ringing under the hammer	,,	3
	Thin layer of marl	-	—
	Bedded chalk, weathering along the lines of lamination, with marly partings, bottom not seen		3 +

Returning now to the main outcrop on the S.E., we may notice a small pit by the road side, half a mile S. of Foulmire (Sheet 47); the following beds are here exposed:—

		Feet.
	Sandy soil and rubbly chalk	5
Melbourn Rock.	Soft laminated chalk, with layers of yellowish marl	2
	Hard greyish-white chalk, with nodular lumps	2
	Thin layer of greenish-grey marl, *O. vesicularis*, about 2 inches.	
	Greyish-white chalk	1

These beds undulated slightly along the face of the pit, but appeared to have a general dip of about 3° to the N.W.; the spot is beyond the line we have taken for the outcrop, and the departure from the normal dip may indicate some connexion with the disturbance to which Wardington Bottom is due.

At the southern end of Melbourn there are two quarries which exhibit good sections of the uppermost beds of the Grey Chalk. The succession seen in the more westerly of these is given below, the beds having a dip of 4° to the S.W., only the lower half of the rock is exposed here; as follows:—

			Feet.
	Soil and chalk rubble	about	3
Melbourn Rock.	Hard rocky chalk, weathering into nodules	,,	1
	Yellowish grey laminated marl	,,	¾ to 1
	Hard nodular cream-coloured chalk, with striated surfaces	,,	1½
	Softer laminated greyish chalk containing numerous specimens of *Ostrea vesicularis* and *Rhynch. plicatilis*	,,	¾ to 1
	Blocky chalk, whitish and tough		4
	Tough lenticularly-jointed chalk, shown in eastern corner of the pit		dug to 15

A similar section is visible in the large quarry a quarter of a mile east, and the full thickness of the rock is between 8 and 9 feet; the dip at this point is in another direction, viz., S. by E. about 5°, and there are several small faults with a throw of 2 or 3 feet down to the west. The pit was commenced near the road in the chalk belonging to the zone of *Holaster subglobosus,* which there comes to the surface and is burnt for lime; it was only as the face was cut backward that the alternations of hard and soft chalk above became visible; these are not used in the kiln as they require a much greater heat for converting them into lime, and the owner has consequently extended his excavations westward into the low anticlinal between the pits, where the lower beds come to the surface.

One of the yellow marl bands may be seen dipping southwards in the railway cutting N. of Royston, and at the waterworks in the town hard beds were said to occur in the well at a depth of about 40 feet from the surface.

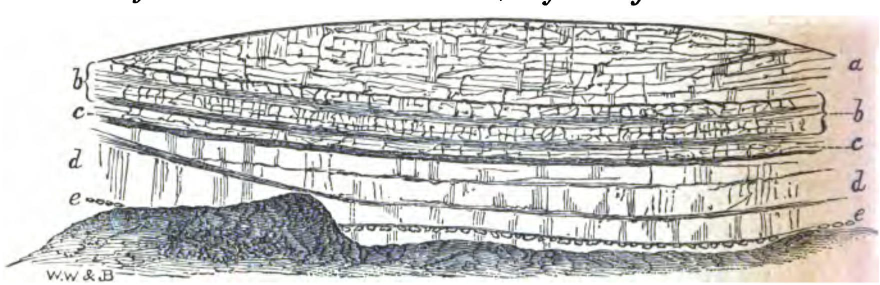
The Melbourn Rock is again seen in a pit by the side of Ermine Street, about a mile and a quarter N.N.W. of Royston, the section showing a preponderance of laminated chalk as follows:—

		ft.
	Thin bedded white chalk, rather hard - -	8
Melbourn Rock.	Evenly bedded yellowish chalk - -	1
	Hard and rough greyish-white chalk -	3
	Yellowish laminated chalk, with marl bands - - - - - -	2
	Soft-greyish thin-bedded chalk -	½ to 1½
	Hard chalk, weathering into nodular lumps	1
	Softer thin-bedded chalk - - -	1
	Irregularly bedded whitish chalk - - -	6

The softer beds contain many fossils, named in the list on p. .

The outcrop of these beds may be traced westward across the fields to the hill south of Ashwell Street on which the tumulus stands, and they are seen again in a pit nearly half a mile west of this point. The section here was noticed by Mr. WHITAKER,* but it has since been cut back, and the upper beds are now more clearly shown; the figure therefore has been slightly altered, and a few lines added to indicate its present appearance.

Fig. 13.—*Section in Chalk Pit S.S.E. of Litlington Church.*



		ft.
	a. Thin-bedded white chalk, rather hard - -	9
Melbourn Rock.	*b.* Hard cream-coloured chalk, rough and rocky, in beds about a foot thick, with a layer of marl at top - -	5
	c. Yellowish laminated chalk, with marly layers and a marked layer of grey marl at the base - -	2
	d. Hard massive creamy-white chalk with marly parting	9
	e. Layer of hard cream-coloured nodules, not persistent, and passing down into iron-stained chalk with nodules in places - - - - -	2

* *Geological Survey Memoirs*, vol. iv. p. 45.

Returning now to the point whence we started, where the line of section cuts the Melbourn Rock, it may be traced under the road which leads down to Cherry Hinton, and followed by contour round the hills between that and the "Quakers' Charity Farm." The well at this farm is sunk down to the base of the Totternhoe Stone, and is 52 feet deep; the well at Bishop's Charity Farm is 132 feet deep, the line therefore passes between these two points. It then bends northward towards Fulbourn, and reaches very nearly to the windmill on the main road above that village; (see Appendix, p. 160).

From this point it trends to the south, but we have had little else to guide us beside general contour in drawing the prolongation of the line, though the spring which rises about half a mile north of Fulbourn Valley Farm may possibly indicate its outcrop.

Thence it is probably continued to the north-eastward above Shardelows Well to the neighbourhood of Wilbraham, for the beds exposed in the cutting at the junction of the old and new railways to Newmarket belong apparently to the overlying zone. The spring north-east of Great Wilbraham probably marks its horizon, but the continuation of the main line of outcrop is entirely conjectural, for though there is a well marked feature, yet we did not find any sections along that part of the country where the marl beds must come to the surface.

The fact of their persistence, however, is proved by the occurrence of a small outlier capping the hill east of Swaffham Bulbeck; the section in the higher part of the chalk pit on the west side is as follows:—

		Feet.
Melbourn Rock.	Broken chalk and indications of yellowish marly layers - - - -	2
	Hard rocky chalk, resting on a thin layer of yellowish marl - - -	2
Zone of *Holaster subglobosus.*	Bedded white chalk - - -	10
	Course of hard yellowish nodules -	1
	Hard white blocky chalk - -	4

These beds appear to dip into the hill towards the east or the north-east.

The yellowish nodular layer is exactly like that seen in the clunch pit at Litlington, and occupies exactly the same position, viz., 9 or 10 feet below the base of the Melbourn Rock. It is interesting to note the recurrence of this horizon at a distance of 20 miles from the point where first noticed, and, although it does not seem to be continuous over the intervening space, it shows how similar were the conditions throughout the area in which these beds were deposited.

A better section of the upper beds is exposed in the larger pit on the north side of the hill, but only in the south-west corner, for here there is a decided dip of nearly 3° to the W.S.W. The hill, therefore, is a synclinal, as is so often the case. The section in this pit is as follows:—

		Feet.
Melbourn Rock.	Chalky soil and hard rubbly chalk -	3
	Buff sandy marl - - - -	1½
	Hard lumpy cream-coloured chalk, *Inoceramus labiatus* - - -	1¼
	Soft thin-bedded marly chalk, *Ostrea vesicularis* - - - -	1
Zone of *Holaster subglobosus.*	Hard white chalk, breaking into small blocks - - - - -	10
	Hard nodular bed, with yellowish stains	1
	Blocky whitish chalk, rather hard, more than - - -	3

The hill about three-quarters of a mile to the S.E. is probably capped by an elongated outlier of these beds, and there may be another small patch by the plantation to the N.E.

FOSSILS from the MELBOURN ROCK.

———	Litlington.	Royston.	Melbourn.	Harston Maggots Mount.	Shelford and Cherry Hinton.	Swaffham Bulbeck.
Lamna subulata (teeth)	×					
Otodus appendiculatus (teeth)	...	×	...	×		
Protosphyræna ferox ?, *Leidy* (tooth)	...	...	...	×		
Cimolichthys ? striatus, *Ag.* (tooth)	×					
Fish vertebræ and coprolites	...	...	...	×	×	
Belemnites plenus (type), *Blainville*	...	×	×	×	×	
„ „ long variety	...	...	...	?		
Exogyra sp.	×	...	...	×		
Inoceramus sp. (? labiatus, *Brong.*)	...	×	×	...	...	×
Ostrea Normaniana, *D'Orb.*	...	...	...	×	×	×
„ vesicularis, *Lam.*, (abundant)	×	×	×	×	×	×
Rhynchonella Cuvieri ?, *D'Orb.*	?	...	...	×	×	
„ plicatilis, *Sby.*, var.	×	×	×	×	×	×
Terebratula biplicata ?, *Sby.*	×					
„ semiglobosa, *Sby.*	×	×	...	×	×	
Cidaris (spine)	...	...	×			

ZONE OF *Rhynchonella Cuvieri.*

The road which passes above the quarries at Cherry Hinton cuts into the chalk which lies above the Melbourn Rock; this was recognised by Dr. BARROIS as belonging to the zone of *Inoceramus labiatus*, but which we prefer to designate by the name of the *Rhynchonella*, so characteristic of the Middle Chalk and specially abundant in this zone.

It is a noteworthy, and at the same time an unfortunate, fact that the pits and cuttings in this part of the Chalk are few and far between; possibly it is not found to subserve any useful purpose and is not worth working: we can therefore only indicate the points where small exposures are to be seen, but as this zone is comprised between two well-marked horizons, the general course of which has been traced on the map, it must occupy the intervening slopes.

The following is Dr. BARROIS' description of the beds seen in the road cutting at Cherry Hinton :—*

Nodular chalk, with some small hard nodules set in a greyish paste, a foot.

White chalk, in platy layers, with *Inoceramus labiatus* and *Rhynchonella Cuvieri*, 3 feet.

The first is probably the uppermost bed of the Melbourn Rock, and the outcrop mentioned by him below the Tumuli called Two-penny Loaves is probably that of the same rock, as described on p. 55. No exposure occurs along the intervening ground, but the thickness as calculated from the section is between 60 and 70 feet.

* Recherches sur les Terrains Crétacées Superieurs, p. 155.

A portion of this zone is exposed in the quarries below Little Trees Hill half a mile south-west of Vandlebury, the section in the more westerly pit being as follows:—

	Feet.
Chalk rubble, resting on a bed of hard rocky chalk - -	6
Marly band with chalk nodules, *Rhynchonella Cuvieri, Cidaris spines*, &c. - - - - - - -	½
Bedded white chalk, with several thin layers of laminated marl; pear-shaped flints occur occasionally, but the only fossils found were *Ostrea vesicularis* and a small *Rhynchonella*, like *Cuvieri* - - - - - about	18

Two slips, with a throw of about 2 feet in each case, have let the beds down to the south. The pit on the south-east slope shows similar chalk in beds averaging a foot thick. This is the lowest horizon at which any flints have yet been found in Cambridgeshire, and must be near the top of the zone; indeed the rocky chalk forming the highest bed in the pit may be the base of the overlying division.

Following the outcrop westward up the valley towards Babraham, a chalk pit will be found in the wood to the north of the cross roads by that village; soft white chalk containing *Inoceramus labiatus* and *Rhynchonella Cuvieri* is seen in this, and in the road cutting close by there is a thin marly band containing loose chalk pebbles or nodules, with a few fossils. This band may be on the same horizon as that noted in the pit below Little Trees Hill; it must at any rate be very near the base of the overlying zone.

The chalk shown in a small pit near Pampisford Hall probably belongs to some part of this division.

Crossing the Cam to Stanmoor Hall, west of Whittlesford, there is a small chalk pit in which 8 or 10 feet of rubbly chalk are seen, overlain by 2 or 3 feet of river gravel; the Chalk here shown is so disintegrated by the percolation of water downwards from the old river-bed that it might almost be taken for re-arranged material; it has a rough lumpy appearance, and the interstices are filled with chalk detritus stained yellow by iron from the gravel above; the hardened lumps of chalk can readily be detached from the matrix, and good typical specimens of *Rhynchonella Cuvieri* occur in some abundance, with fragments of *Inoceramus*.

Similar chalk is seen in a pit near Triplow Church, and the base of the zone is of course seen in the pits previously described near Foulmire and Melbourn. It likewise overlies the Melbourn Marl in the cutting N.N.E. of Royston, but this is weathered and overgrown.

Returning now to the point whence we started above Cherry Hinton, the beds of this zone must crop out along the northern slopes of the Gog-Magog Hills by Bishop's Charity Farm, and the chalk seen below the rock-band in the clunch pit on Missleton Hill belongs either to the uppermost part of this or to the base of the overlying zone.

No other exposure occurs till we reach the cutting on the Cambridge and Newmarket line, a mile S.E. of Great Wilbraham; this was widened in 1875, and the following section exposed:—

Light-coloured sand with flints - - -	about 6 feet.
Bedded white chalk without flints, containing *Inoceramus labiatus, Terebratula semiglobosa*, and *Echinoconus globulus* - - - - - -	about 15 feet.

In the gravel and chalk pit half a mile to the south disintegrated rubbly chalk without flints is seen to a depth of about 8 feet. Beyond this point there are no chalk pits in this zone, and patches of gravel conceal some portions; but it probably occupies the ground by Allington Hill Hare Park, and Newmarket Heath.

List of Fossils from the Zone of Rhynchonella Cuvieri.

	Stanmoor Hall.	Babraham.	Little Trees Hill.	Wilbraham Railway Cutting.	Missleton Hill (lower part).
Ptychodus decurrens ?, *Ag.*	...	...	...	...	×
Inoceramus mytiloides, *Mant.* labiatus *Brong.*	×	×	...	×	
„ var. problematicus, *D'Orb.*	...	×	...	...	×
Ostrea vesicularis, *Lam.*	...	×	×	...	×
Rhynchonella Cuvieri, *D'Orb.* (type)	×	×	×	...	×
„ „ var. (or young)	...	×	×	...	×
„ Mantelliana, *Sby.*	...	×			
„ Martini, *Mant.*	...	×			
Terebratula semiglobosa, *Sby.*	...	×	...	×	×
Terebratulina gracilis, *Schloth.* var. lata, *Ether.*	...	×	...	...	×
Cidaris dissimilis ?, *Forbes* (spines)	...	×	×	...	×
Echinoconus globulus	...	...	...	×	
„ subrotundus, *Mant.*	...	...	...	...	×
Serpula antiquata ?, *Sby.*	×				

Zone of *Terebratulina gracilis.*

Referring again to the line of section across the Gog-Magog Hills (Plate 6), it will be seen that a marked rise of the ground occurs by the tumulus marked on the Ordnance maps above the end of Worts Causeway; this seems to be caused by the outcrop of some hard beds which appear to underlie the higher part of the Wandlebury district, and to form the base of the *Terebratulina gracilis* zone.

By combining the information acquired during the survey of the district with that obtained in running the line of section, we have found it possible to indicate the outcrop of these beds by a line which may be taken as generally correct, though it has no more pretensions to detailed accuracy than any of the other zone-lines on the map.

By a reference to the map (Frontispiece) it will be seen that this line exactly circumscribes the numerous patches of gravel which cap the Gog-Magog Hills, and it is probably as much owing to the existence of this hard rocky chalk, as to the protective influence of the gravels, that these hills have resisted denudation and assumed their present form.

The continuation of this line to the N.E. is taken outside a series of sections in which the fossils characteristic of this zone have been found, and along the flank of what may be called the third step in the chalk escarpment; this is doubtless caused by the persistence of similar hard beds along its course, but the evidence in Cambridgeshire is not sufficient to make it clear whether there is any definite and constant bed which can be taken

as forming the base of the zone. The question too of the further subdivision of the Middle Chalk is one that cannot be solved in Cambridgeshire, though there would certainly appear to be palæontological evidence for separating off the upper 50 feet of this zone, and constituting them into another division. We propose therefore to describe in the first place those sections exposing the lowermost beds of the zone, and subsequently those in the upper division below the Chalk Rock.

Lower Division or Vandlebury Beds.

These beds are not exposed along the line of section across the Gog-Magog Hills, but they are to be seen in the chalk pit near the top of Missleton Hill, a mile S.W. of Fulbourn, where the succession is as follows:—

	Feet.
Gravelly soil and chalk-rubble - - - -	3
Hard nodular chalk, with yellowish stains and semi-crystalline nodular lumps (many fossils) - - -	4
Massive white chalk, *Inoceramus labiatus* - - -	7
Platy chalk, with a layer of grey marl - - -	0½
Massive white chalk with a few flints and many fossils, *Terebratulina gracilis* common - - - -	8

Taking the layer of marl as an indication of the bedding, the dip is found to be 5° or 6° to the E.S.E.

If the hard rocky chalk at the top of this pit be taken as the basement-bed of this division, the massive white chalk below must of course be classed with the underlying zone of *Rhynchonella Cuvieri;* the whole section is indeed very like that in the quarry at Little Trees Hill (see p. 61). Hard rocky chalk occurred there in a similar position, and if this should prove to be a persistent layer it might receive the name of the Wandlebury Rock.

Missleton Hill is formed by a small outlier of this rock, and the small conical hill to the southward appears to be just capped by the same bed, which probably takes the ground again north of Fulbourn Lodge and underlies the hilly ground to the south, though we cannot point to any other spot where it is actually exposed.

In the small pit north of Fulbourn Lodge 10 or 12 feet of bedded white chalk are shown, containing *Terebratulina gracilis* and *Rhynchonella Cuvieri;* and the little knoll called Megs Hill, three-quarters of a mile south of the Lodge Farm, exposed similar beds, an excavation on one side showing hard white chalk with a band of marl containing *Terebratulina gracilis.* Another small pit occurs at the eastern corner of the plantation on Signal Hill.

The section in the road-cutting leading N.E. from Babraham has already been mentioned; the band of marl here shown may be the same as that at Megs Hill, but there are so many marly layers in the Middle Chalk that it is unsafe to attempt any correlation at present; this layer is however remarkable for containing *Rhynchonella Mantelliana,* and *Rh. Martini* which have not elsewhere been found above the Melbourn Rock.

The railway cutting near Babraham is too overgrown for the chalk to be well seen, and the next exposure is in a small pit on the hill slope south of Little Abington Grange. Here rather hard white chalk is seen, somewhat blocky, and not very distinctly bedded, but broken up by strong vertical and inclined joints, the sides of which are much iron stained, but this colouring is probably due to the gravel capping the hill above; a few silicified Ventriculites occur, but no other flints were to be seen, and fossils were scarce.

Beyond this we cannot indicate the course of the zone with any certainty, but we should expect it to occur in the neighbourhood of Pampisford Hall, where the hills present a steep 'scarp like that which borders the Gog-Magogs. Thence it probably runs back for some distance up the valley of the Cam, but we have nowhere observed any exposure.

Near Royston there are two quarries which give good sections of this part of the Chalk. Since the surface at the Royston Waterworks appears to be about 40 feet above the Melbourn Rock (see p. 58), the floor of the deeper of these pits, about two furlongs to the S.E., cannot be much above the same level; the section here is as follows:—

	Feet.
Thin-bedded chalk, yellowish (? stained from above) with scattered elongate and root-like flints - - -	12
Layer of greyish laminated marl, 3 inches.	
Massive thick-bedded chalk with a line of scattered flints at the top - - - - - - - -	16
Layer of irregular flint nodules.	
Thick-bedded white chalk - - - - - -	8

These beds dip slightly S.E. The only fossils found were *Discoidea Dixoni*, *Micraster sp.* and *Lima spinosa*.

At the lime-kiln, 3 furlongs S.W. of the Church, a similar section is shown; the chalk dipping at 5° to the S., and containing scattered flints of a round or oval shape; many of these when broken open were found to enclose Siphoniform sponges. *Inoceramus Brongniarti*, *Lima spinosa*, and *Terebratula semiglobosa* were obtained here.

Returning now to the sections on the north side of the line of section, the first we meet with is the cutting on the abandoned railway near Worsted Lodge. This exhibits bedded white chalk, with occasional irregular flints in rather indefinite bands; these flints have assumed very remarkable forms, being mostly long, narrow, and root-like, many are nearly cylindrical, and often lie almost vertically in the chalk, as if they were sponges silicified in the position of growth, but others are of very irregular form.

The harder beds stand out from the rest, and appear to be dipping east; they contain fragments of Inocerami, and other fossils are not rare, the most notable being *Echinoconus subrotundus*, *Terebratulina gracilis*, young *Rhynchonella Cuvieri*, and a species of *Parasmilia*.

In the next railway cutting at Mutlow Hill similar beds are traversed, but they would appear to form an outlier, the main outcrop coming on further east near Bedford Gap; this cutting is about 12 feet deep in laminated white chalk, breaking up into small brick-shaped fragments; flints occur scattered irregularly along one or two lines; towards the N.E. end some hard beds crop out, like those near Worsted Lodge, and appear to dip slightly to the south, though the real dip may be S.E.; they contain flints, *Inocerami*, and other fossils.

These hard courses must lie somewhere near the base of the zone, and it is possible that they are on the same horizon as the Vandlebury Rock, though they are somewhat different in character.

Upper Division.

The upper part of this zone appears to consist of soft white homogeneous chalk, with occasional layers of marl; flints are abundant at certain horizons, but there are spaces 10 feet or more in thickness, which do not contain any. Many of the flints assume curious forms, and silicified sponges and Ventriculites are generally common.

There are very few exposures of these beds in our area, but they form the slopes below the outcrop of the Chalk Rock, and may perhaps be regarded as an expansion of the zone of *Holaster planus*; this, however, is a point that requires further investigation, but palæontologically they certainly appear to be linked to the Chalk Rock rather than to the zone below.

The quarry which is nearest to the line of section is at the lime kiln, marked on the Ordnance map north of Linton; in this white bedded chalk without flints is exposed; some of the fossils belong to species which are now met with for the first time, such as *Micraster cor-bovis?* and *Holaster planus*; *Ventriculites* too are common, and the fauna approaches to that of the Upper Chalk, so that these beds are probably not far below the Chalk Rock.

The chalk exposed in the pit east of Great Chesterford, described in the Memoir on Sheet 47, p. 6, belongs probably to this division.

Near Ickleton, on the west side of the Cam Valley, there are two pits in the higher part of the Middle Chalk; the first of these is six furlongs S.S.W. of Ickleton Church, and shows thin-bedded white chalk with a few scattered flints. *Ventriculites* are common, but other fossils scarce. The second, a mile and a half W.S.W. of Ickleton, is in similar chalk, and yielded the following fossils; *Scaphites æqualis*, *Inoceramus Cuvieri?* and *Terebratula semiglobosa*.

Returning to Sheet 51 no pit or exposure of any consequence is met with for some distance to the northward of the section line; about a mile east of

Six-mile Bottom Station, and just beyond Westley Lodge, there is a pit in which the following beds are seen:—

	Feet.
White chalk, rather broken, without flints, but with a few nodules of iron pyrites near the bottom - - -	12
Thin layer of grey clayey marl - - - -	¼
White bedded chalk, full of finger-like flints of all sizes, with a few more massive nodules - - - -	5

A short distance N.E. of Dullingham Station is another quarry in which similar chalk is shown, as follows:—

	Feet.
Bedded white chalk without flints - - - -	4
Thin bedded chalk, with many flints of various sizes, some long and irregular, others thin and flattish, and others large and nodular - - - - - -	6
White chalk, rather hard, without flints - - -	10

The very uppermost beds of the zone are shown in some of the pits where the Chalk Rock is exposed, and are mentioned under that head.

FOSSILS from the ZONE of TEREBRATULINA GRACILIS.

——	Lower Beds.			Upper Beds.			
	Missleton Hill (Upper Beds).	Worsted Lodge.	Mutlow Hill.	Linton.	Westley Waterless (two pits).	Dullingham, near Station.	Carleton Grange.
Scaphites æqualis ?, *Sby* (Ickleton).							
Inoceramus Brongniarti, *Sby.* -	...	...	...	...	×	×	
„ mytiloides, *Mant.* -	×	×	×				
„ problematicus, *D'Orb.* -	×						
Lima spinosa, *Sby.* - - -	...	...	...	×	×	×	×
„ striata, *Sby* - - -	...	×	×	×			
Ostrea vesicularis, *Lam.* - -	×	...	×	×	×	...	×
Pecten Beaveri, *Sby.* - - -	...	...	...	×			
Rhynchonella Cuvieri, *D'Orb.* -	×	...	×	×		×	
„ „ var. (or young)	×	×	×				
„ plicatilis ?, *Sby.* -	×	×	...	...	×		
„ Reedensis, *Ether.* -	...	...	...	...	×		
Terebratula semiglobosa, *Sby.* -	×	×	×	×	×	×	×
Terebratulina gracilis, *Schloth.* - var. lata, *Ether* -	×	×	×				
„ striata, *Wahl.* - -	...	×					
Cidaris dissimilis, *Forbes* (spines) -	×	×					
„ sceptrifera, *Mant.* -	...	...	...	...	...	×	
Cyphosoma radiatum, *Sorig.* - -	...	...	...	...	×		
Discoidea Dixoni, *Forbes* (Abington).							
Echinoconus subrotundus, *Mant.* -	...	×	×				
Holaster planus, *Mant.* - -	...	...	...	×	×	×	
Micraster breviporus, *Ag.* - -	...	...	...	...	×	..	×
„ do. or cor-bovis, *Forbes* -	...	...	...	×	×		
Parasmilia sp. - - -	...	×					
Ventriculites mammillaris, *Smith* -	...	...	...	×			
„ impressus, *Smith* -	...	...	...	...	...	...	×
Dercetis (? Terebella) - -	...	...	...	...	×		

CHALK ROCK.

The Middle Chalk passes upwards into a band of hard crystalline chalk, which Mr. WHITAKER has named the "Chalk Rock." It may be traced, perhaps with slight breaks, quite across this district, its line of outcrop constituting the division between the Middle and Upper Chalk.

The rock is shown less distinctly than elsewhere where the line of section crosses the area, but the position we have there assigned to it may be taken as approximately correct. Following the method adopted at p. 22, the sections will be noted in order to either hand from the line of section.

To the south and west the outcrop passes through Linton, then sweeping round by Abington and Great Chesterford Parks, it runs along the eastern flank of the valley, which it crosses to the south of Chesterford. Rising again on the other side it follows a line roughly parallel to that of the Boulder Clay, but for several miles its course is not distinctly defined. It passes west of Heydon, near Chishall and Barley, whence to the edge of the map north of Tharfield it follows a line of disturbance.

To the north and east from the line of section the Chalk Rock runs to Balsham, thence, following the shape of the ground, round by Congers Well and Linnet's Hall to Westley Waterless; beyond that village, and about a mile west of Dullingham, it passes under the Boulder Clay.

Analyses of two Specimens of Chalk Rock from near Newmarket (51 S.E.), by DR. FRANKLAND, F.R.S.

Composition in 100 parts.

Moisture at 100°	·13
Organic matter	·32
Sesquioxide of iron, partly present as protoxide	·64
Alumina	·62
Calcic carbonate	97·25
Magnesic carbonate	Trace.
Phosphoric anhydride (P_2O_5)	·2[illegible]
	99·17

Moisture at 100°	·20
Silica	·31
Sesquioxide of iron	·69
Alumina	·64
Calcic carbonate	98·57
Phosphoric anhydride (P_2O_5)	·20
	100·61

Both to the north and south of Linton, the line has been traced solely by the lumps of hard chalk (resembling the rock as seen elsewhere) found on the surface. About three-quarters of a mile west of the railway station the line is lost beneath the Boulder Clay, and is shown as following the shape of the high ground by Abington Park. A mile south of this place it again comes to

the surface, but passes under the clay again almost immediately, just running through a chalk pit in which a good section is shown ,with a slight dip to the south.

		Feet.
Chalk with flints - - - - - - - -		6
Chalk Rock.	An irregular layer of rubbly crystalline yellowish Chalk, in lumps enclosed in a marly matrix, and containing fossils, phosphatic nodules, and decomposed pyrites -	2 to 5
	Marly Chalk - - - - - - -	
	Hard crystalline Chalk, passing into the bed below -	
Soft tabular Chalk, with few flints - - - - -		10

The upper surface of the Chalk Rock presents a definite line; the lowest bed passes gradually into the soft white Chalk below, and varies from a few inches to a foot in thickness.

On the hill flank, east of Great and Little Chesterford, hard Chalk again occurs at the surface, and half a mile east of the latter place a fair section of the rock may be seen by the roadside.

From this point, for several miles westward, the Chalk Rock is not exposed, the numerous pits in the Chalk near where it occurs being either above or below its horizon.

There is a pit S.W. of Heydon, in which the Chalk Rock (?) is shown dipping a little west of north at an angle of 25°; south of Barley it dips 40° in the same direction. Further westward the dip is found to have increased to 60°, still west of north, but another pit still further westward shows a dip of 22° only, and due north in direction.

The last-named three pits, all evidently on a line of flexure or disturbance, are so situated that a semicircular curve passing through them just encloses the head of the valley called Wardington Bottom, the initial cause of which is probably this downthrow (or rather depression) of the Chalk. The pit S.W. of Heydon is probably not on, but somewhat to the south of, the line of greatest flexure; the other three pits all present exposures of the Chalk Rock, which fact is somewhat remarkable. These sections have already been described, and the line of flexure noticed in the Memoir on Sheet 47 (pp. 7–11, Figs. 1 and 2).

In the pit at Smyths End, and in that north of Reed, it is remarkable that, notwithstanding the high angle of dip, the Boulder Clay is resting on a surface of the beds nearly parallel to their stratification. At first sight this fact would seem to indicate that the clay was deposited upon them when horizontal or nearly so, and that the disturbing force had acted on the beds in Post-glacial times; but it is more likely that during the Pre-glacial cutting back of the escarpment, and after the bending of the Chalk, the beds slipped off each other in masses along the planes of bedding, and that the Boulder Clay was deposited against the slope thus formed. The tongue of Boulder Clay protruding from the edge of the main mass to the pit north of Barkway (see Fig. 2, p. 8, *Geol. Surv. Memoir*, on Sheet 47) offers no evidence either way, as it seems to have been forced in under a mass of rubbly chalk. Such sliding down of the beds, probably in large masses, as denudation went on, would materially lessen their cohesion, and render them more easy of removal by water than the parts not so disturbed on either hand. The escarpment would be more rapidly cut back at

this spot than at others, until a point was reached where the beds folded back into their normal position; in two of the pits this point is exhibited.

Passing to the north and east from the line of section we come to the site of an old Clunch pit, marked on the Ordnance map, now filled in and overgrown; but its name implies a bed of hard chalk, which is probably the Chalk Rock. The line is drawn through this pit, by Balsham, and on to the high ground, where, 1½ miles N.W. of that village, hard crystalline Chalk is scattered over the surface of the fields. The same indications occur just west of Conger's Well, and by the roadside, a quarter of a mile north of Wratting Grange, there is hard crystalline yellow chalk, which doubtless is Chalk Rock. Similar Chalk is seen in the bank, near the top of the hill, by Linnet's Hall, and from this point the line runs by contour to a pit a quarter of a mile S.E. of Carleton Grange, which is partly grown over, but from one face it has been tunnelled in several directions, the Chalk Rock, about 3 feet thick, forming the roof.

A little further on, in a pit three-quarters of a mile S.W. of Westley Waterless, the following section is seen, in which the rock can at once be identified:—

	Feet.
Upper Chalk, with flints - - - - - - -	8
Chalk Rock; crystalline yellowish Chalk, much broken up; the top presents a definite line, the base passes down into the bed below - - - - - - - - -	2 to 3
White Chalk, with few scattered flints.	
The beds are horizontal.	

There are three pipes, two filled with gravel, the other with brown and grey clay. These run down through the Chalk Rock into the Chalk below.

North of this and half a mile N.W. of Westley there is another pit which appears to be on the same horizon, though the rock here is not so compact or so clearly marked as elsewhere; the section is as follows:—

	Feet.
Hard chalk with several yellowish layers, near the base containing lumps of hard crystalline chalk and flint nodules of irregular shapes	15
Two thin layers of tabular flint with white chalk between - -	2
White chalk with a few flints - - - - - -	5

The dip is about 2° to the S.E. At the S.W. and N.E. corners of the quarry the layers of tabular flint cease to be continuous, and pass into lines of nodules. The fossils obtained from the hard chalk above are those which are elsewhere found in the Chalk Rock (see list below, No. 2).

In the next pit to the N.E., two furlongs W. of Stetchworth Church, a more distinct band of hard yellowish crystalline chalk is exposed at the bottom, and contains a similar assemblage of fossils.

The Chalk above contains flints arranged in regular and horizontal layers, but some of the flints are remarkable for their great length; these measure two feet or more, and pass vertically through the beds of chalk, bulging slightly at the divisional planes between the beds. From this chalk the fossils listed on p. 69 were obtained.

FOSSILS from the CHALK ROCK.

—	Reed and Barkaway.	Great Chesterford.	Carleton Grange, S.E. of.	No. 1 Westley Waterless.	No. 2 Westley Waterless.	Stetchworth.
Ammonites Prosperianus, *D'Orb.* -	×					
Scaphites æqualis ?, *Sby.* - -	...	...	...	...	...	×
Turbo gemmatus, *Sby.* - -	×	...	...	×	×	
Solarium, sp. - - -	×					
Pleurotomaria perspectiva, *Mant.* -	...	...	×			
Inoceramus Brongniarti ? - -	×	×	...	×	×	
Lima spinosa, *Sby.* - - -	×	×	...	×	×	×
„ Hoperi, *Mant.* - -	...	...	...	...	×	
Ostrea, sp. - - - -	...	...	...	×	×	×
Rhynchonella limbata, *Schloth.* -	...	×				
„ plicatilis, *Sby.* - -	×	×	...	...	×	
„ Reedensis, *Ether.* -	×	...	...	×	×	×
Terebratula carnea, *Sby.* - -	×	×	×	?	×	×
„ semiglobosa, *Sby.* -	×	×	...	×	×	×
Ananchytes ovatus, *Leske* - -	...	×	...	×	×	
Holaster planus, *Mant.* - -	×	...	×	×	×	×
Micraster corbovis, *Forbes* - -	×	...	...	×	×	×
„ cor-anguinum, *Leske*, var.	×	×	×	...	×	
„ breviporus - - -	...	...	...	...	×	
Cidaris, sp. (spine) - - -	×					
Parasmilia centralis ?, *Mant.* -	×					
Ventriculites mammillaris, *Smith* -	×					
„ radiatus, *Mant.* -	×	...	...	×	×	
„ impressus, *Smith* -	×	...	×			

The first two columns are taken, with corrections and additions, from the "Geology of the N.W. part of Essex, &c.," p. 9.—*Geological Survey Memoir*, 1878.

UPPER CHALK.

ZONE OF MICRASTER COR-BOVIS.

Towards the close of the period of the Middle Chalk there was probably a slight upward movement of the sea-bottom, or a somewhat different distribution of sea and land. The change was gradual, as is indicated by the Chalk Rock, which passes up from the pure white chalk, into a hard and more or less crystalline or compact rock, tinged slightly yellow by the presence of a small percentage of oxide of iron.

A still further change caused a cessation of this deposit, and perhaps an erosion by deep currents over a greater part of the area. The sharp line of demarcation between this rock and the overlying Upper Chalk seems to indicate such conditions. During the period in which the Upper Chalk was deposited, the water must have been equally, or even more, charged with silica, which it threw down in a different manner, as it is now found as flint in

numerous horizontal bands of nodules and thin tabular layers. The tabular flint in joints and fissures was probably formed after the consolidation of the chalk, and may be forming even at the present time.

As regards the occurrence of flints in regular layers in the Chalk, we would make the following suggestions. It is generally believed that every nodule of flint has been formed around some organic nucleus, and this may or may not be the case; but it is at all events probable that decomposing organisms attract and retain silica from solution. When the chalk was first deposited it must have been in the form of a soft calcareous mud, much less dense than in its present condition as chalk, a foot of which represents several feet of the substance in its earlier state.

The silica now found as flint would at that time have been equally distributed throughout the water by which the unsolidified portion of the mass was permeated.

We may assume that the surface of this mud was at some particular period strewn with organic remains in varying stages of decomposition. It matters not (for the purpose of this argument) what chemical actions were set up, or how they were originated, since we find that the silica was precipitated or deposited in and around the organic remains on the sea-floor. And when once in action the process, whatever it may have been, continued, and the silica accumulated along the same plane of decaying organism, notwithstanding the mud that was still being thrown down, and by which the forming line of flints was buried. We assume that the force, whatever it may have been, would act upwards and downwards through some definite thickness of the mud, and that until the sediment had attained a certain height above such line, the silica would continue to segregate along it, in and around its organisms. When that point was reached no more silica would segregate along that particular zone, the organic remains on the then existing floor would in a similar manner serve as the nuclei of a new layer, and another line of flints would be at once commenced.

As the sediment increased, consolidation proceeded, and the deposit varied in density throughout, from the compressed chalk with layers of flints to mud in which flints were being formed at and near the surface. This fact is worthy of attention, because any irregularity in the surface (or other plane along which flints were formed) would be very considerably modified on compression. If one foot of chalk represents 10 feet of the original mud, any old hollow or ridge, varying from a plane to the extent of 10 feet in a given distance, would now vary from that plane one foot only in the same distance, and such variation would perhaps be scarcely perceptible.

The organic remains found as fossils in the Chalk are not necessarily in layers, indeed they are constantly found without regard to any such definite arrangement; their position, therefore, will not explain the fact that the flints are so frequently found in regular and parallel lines. There are, we admit, many difficulties in the way of the foregoing explanation, still we venture to suggest that as it indicates a new point of view from which this question may be regarded, it is worthy of some consideration. What we say is

this, that once given the initial plane of segregation, the force (whatever it may have been) by which the silica was attracted would act only through a constant thickness of similar deposit, and that the layers of flints so formed would in consequence preserve an approximate parallellism.

Only a very small portion of the area described in this memoir is occupied by the Upper Chalk, except where it occurs beneath the Boulder Clay. The boundary of the latter runs roughly parallel with, and at no great distance from, the outcrop of the Chalk Rock, leaving exposed a narrow belt only of the Upper Chalk.

There are many pits and sections in which the chalk is exposed, owing probably to its value, in former times if not now, for spreading over the surface of clay lands; certainly many pits occur quite near to the clay boundary. The chalk presents the usual characters, being a soft earthy limestone, with occasional bands of harder or more siliceous chalk, and layers of flint, either tabular or in nodules. With few exceptions the deposit lies in a horizontal position, or nearly so; where any dip is obtainable it is generally in a S. and E. direction; the one notable exeption being the line of flexure S. of Royston, see p. 67.

Proceeding, as before, from the line traversed by the section, westward by Linton, the Upper Chalk with a few flints is seen in the railway cutting; again in a pit by Hadstock, and is then lost under the Boulder Clay. It is not shown again on this side of the Granta, except in one pit, where it emerges S. of Great Chesterford Park.*

Between Chesterford and Heydon several pits are found, in all of which the Chalk contains flints, and appears to be horizontal; N. of Heydon it is so, but from this point commences the deflecture to the N. previously described. The Upper Chalk is seen in all the pits through which the line of disturbance runs, and in several others between that line and the Boulder Clay. It has almost, if not quite, resumed its horizontal position before passing under the clay, although in one case, half a mile S.E. of Smyth's End, it still retains a dip to the N. of 12 degrees.

These, and some pits near Tharfield, have been described in the memoir on Sheet 47.

On the E. of the section line, a pit between Ashdon and Bartlow gives the following section:—

	Feet.
Boulder Clay (at one corner only) - - -	2
Sandy clay, with stones - - - -	1 to 2
Upper Chalk, with flints and thin marly bands; beds flat.	

At the top of the Chalk is the hard crystalline band, 3 inches thick, so often found at the base of the Boulder Clay where resting on Chalk. (For remarks on the origin of this hard bed, see Memoir on Sheet 47, p. 60.)

About a mile and a half to the N.E. are two other pits, exhibiting good sections.

At the "Middle of the World," a mile S.W. of West Wickham, are some pits in Chalk, with few flints, bedding horizontal, while another pit half a mile W. of that village shows similar chalk, with tabular flint in many diagonal joints, and dipping 3 degrees to S.E.

The lime kilns just N.W. of Balsham give a good section; the flints are not numerous, but they enclose an unusual number of fossils, *Spondylus spinosus* being abundant.

Another pit N.N.E. of Balsham and half a mile N.W. of West Wratting shows chalk with layers of black flint, and tabular flint in many diagonal joints, the bedding being horizontal.

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* See Explanation of Sheet 47, p. 7.

The sections near West Wratting and Stetchworth, exposing the base of the Upper Chalk, have already been described. An old pit about a mile S.E. of Carleton Grange is probably above the Chalk Rock. The only fossil found was *Epiaster gibbus*.

LIST of FOSSILS from the ZONE of MICRASTER CORBOVIS.

——	Chesterford and Saffron Walden.	Balsham Lime Kilns.	Balsham, N.N.E. of.	Stetchworth.	Westley Waterless.
Inoceramus Cuvieri ? - - - -	×				
Lima Hoperi, *Mant.* - - - - -	×	...	...	×	
„ spinosa, *Sby.* - - - - -	×	×	×		
Pinna decussata, *Goldf.* - - -	...	×			
Rhynchonella plicatilis, *Sby.* - -	...	?			
Terebratula carnea ? *Sby.* - - -	...	×			
„ semiglobosa, *Sby.* - -	...	×	×	×	
Terebratulina striata, *Wahl.* - - -	...	×			
„ gracilis, *Scloth.* - -	...	...	...	×	
Ananchytes ovatus, *Leske* - - -	×	...	×		
Cidaris sceptrifera, *Mant.* - - -	×	×	×		
Cyphosoma radiatum, *Sorig.* - - -	...	×	...	...	×
Micraster cor-anguinum, ? *Leske* - -	×	...	×	×	
„ corbovis, *Forbes* - - -	...	×	×	×	×
„ cortestudinarium, *Goldf.* (var. brevis)	×	×	×	×	×
„ (Epiaster) gibbus, *Lam.* - -	×				
Parasmilia centralis, *Mant.* - -	×				
Ventriculites, sp. ? - - - -	×	...	×		
Coscinopora globularis, *Phil.* - -	...	...	×		
Alecto, on Micraster corbovis - -	...	...	...	×	

CHAPTER VII.

GLACIAL DRIFT.

Between the Upper Chalk and the next newer formation occurring within the limits of our district (map, plate 7), there is a very great gap. All the Tertiary beds are absent; all traces of them have been removed, unless the few green-coated flints described as occurring in a small pipe in the Chalk be a trifling exception (See Explanation of Sheet 47, p. 10).

Neither do we find any of the earlier Glacial deposits, although these occur a few miles only to the south; but, as has been remarked by one of us, "the gravels can in no instance be traced up to the escarpment of the Chalk, or, in other words, beyond a certain definite level. It is not that they disappear beneath a great thickness of Boulder Clay to reappear at its opposite boundary; on the contrary, it is evident that they gradually thin out, and a few miles before the escarpment is reached we find the Boulder Clay overlapping them, and resting directly on the Chalk."*

There are a few unimportant exceptions where local deposits of gravel occur at or near the base of the Boulder Clay, but these are not to be regarded as the representatives of a distinct period or of a set of physical conditions differing from those by which the clay was produced.

The line of section, Plate 6., intersects one of these local patches between Ashdon and Bartlow, where the railway cutting shows a thin bed of sand between the Chalk and the Boulder Clay; in the brook about half a mile to the S.E. a thin bed of gravel occurs in the same position; in the chalk pit, noted on p. 71, it has thinned out to a mere sandy base to the Boulder Clay. A similar bed of gravel occurs beneath the Boulder Clay on the N. side of the village of Hadstock; the two are probably continuous beneath the Boulder Clay.

Another possible exception is in the Cam Valley, at Chesterford, where loam occurs in connexion with and probably under Boulder Clay, and an extension of the same, or equivalent, deposits at Whittlesford. For a description of the former the reader is referred to the Memoir on Sheet 47, p. 39.

Boulder Clay.

This deposit covers the western side of the district, skirts its southern margin (that is, the Chalk escarpment), caps the Chalk outliers of Orwell and Coton, and the ridge N. of St. Ives, and occurs in isolated patches at various levels.

The clay on the top of the Chalk range is the edge of the wide sheet which covers large parts of Essex and Hertfordshire. It presents a very irregular boundary, which, however, conforms generally to the contour of the ground, but in some cases, where

* Penning, *Quart. Journ. Geol. Soc.*, vol. xxxii. p. 191.

the clay occupies an old slope or channel, it runs out in long tongues or down to lower levels. In one instance, to be more particularly referred to hereafter, about Hildersham and Abington it rests on an old sloping surface, from the top of what may be called an outlying part of the escarpment down to the valley below. The small outliers at some distance from the main mass are also at considerably lower levels. The reasons for this, and the conclusions drawn from the mode of occurrence of these remnants, will presently be considered.

The Boulder Clay has several constant characteristics, and some that vary according to local circumstances. It never shows any signs of stratification ; in section it is hard and dry, of a dark grey or bluish colour, but weathering to a drab or light grey to a depth of some feet, in which weathered part a majority of the sections of course occur. It varies according to the nature of the rocks in its immediate neighbourhood, and its base, which in section is always clearly defined, is sometimes of a sandy nature, while occasionally it consists of a hard bed or thin band of crystalline siliceous limestone. The probable origin of this bed has been discussed in the Memoir on Sheet 47 (p. 60).

The clay encloses many lumps of hard *or hardened* chalk, more or less rolled, and frequently striated, but its mass often resembles in composition the rock on which it rests. North of St. Ives the clay could scarcely be distinguished, but for its boulders, from Oxford Clay; near Bourn it resembles Gault, and in the neighbourhood of Balsham it is like, and indeed mainly consists of, reconstructed chalk. Boulders of other rocks are scattered indiscriminately throughout it ; they are of all sizes and of many kinds— Carboniferous Limestone, sometimes polished and grooved, sandstones of like age, Oolitic limestones, quartzites, gneiss, mica-schist, and quartz, fragments of igneous rocks not being uncommon.

Thin lenticular beds of sand, loam, or gravel are sometimes seen within the mass of the Boulder Clay, but the only certain observed instances in this area are a bed of loam in the railway cutting W. of Newnham Hall, between Ashdon and Bartlow, which appears to occupy that position, and a thin band of laminated loam near the top of Barrington Hill.

As there are many sections, such as pits, ponds, road and railway cuttings, in which the Boulder Clay is exposed, and as they vary but little (except on different formations), they will not be described in detail. In the following list are named some of the more important exposures, notes being given of those only which present some feature worthy of remark.

Pits, &c. Westwards from the Line of Section.

Road-cutting half a mile east of Babraham ; 5 or 6 feet of coarse gravel with large boulders is here seen partially overlaid by greyish white clay full of chalk pebbles.

Railway-cutting, 6 furlongs E.S.E. of Babraham, shows sandy and chalky Boulder Clay, with many large stones and boulders of various igneous and sedimentary rocks. Among these fragments of the Lincolnshire Oolites were recognised. The deposit is 5 or 6 feet thick, and rests on disturbed Chalk.

Cutting on road from Linton, near the top of Barrington Hill.

Two pits just N.E. of Abington Park, in one of which the clay is seen resting on the Chalk.

Railway cutting between Ashdon and Bartlow.
Pit N.W. of the village of Hadstock.
Chalk pit just north of Little Chishall Church, with the "hard-bed" at the base of the clay (see *Memoir on Sheet* 47, p. 60).
Chalk pit at Smyth's End (*Ibid.*, p. 7).
Chalk pit by Newsell's Bury (N. of Barkway) (*Ibid.*, p. 8).
Chalk pit 2 miles south of Royston (N. of Reed) (*Ibid.*, p. 8).
The clay is also shown by a slip on west side of road just opposite the latter pit, where it yielded several "coprolites" from the "Cambridge Greensand," which bed occurs at a level of 300 or 400 feet below, this point being near the summit, whilst the coprolite bed is at the base of the Chalk escarpment.
Pit by the road side, half a mile west of Tharfield.
Pond in small outlier, 1½ miles south of Royston.
Road cutting in small outlier, three quarters of a mile south of Royston.
Drain (probably now filled up) in small outlier, 1½ miles N.E. of Royston.

Pits, &c. Eastwards from the Line of Section.

Railway cutting two miles east of Bartlow. This must at one time have presented a fine exposure 50 or 60 feet in depth. The slopes are now covered by grass, but here and there some fine smoothed and striated boulders protrude.
Pits and ponds in the village of Balsham.
Road cutting between West Wratting and Wratting Grange, where the junction with the Chalk is shown.
Railway cutting west of Dullingham station. Shows Boulder Clay and Chalk, with the "hard bed" between.

Sections in the Separate Mass on the Western Side of the District.

Old quarry south of Haslingfield; Boulder Clay on Chalk.
Barrington Clunch Pit (see p. 53).
Pit by roadside north of Orwell (see p. 53).
Eversden Quarry (see p. 53).
Road cutting north of Arrington. Boulder Clay on Chalk.
Railway cuttings S.E. of Bourne. Good sections of the clay, which here rests on Gault; and, but for its included boulders and chalk fragments, greatly resembles Gault in general appearance.
Hardwick; large ponds.
Madingley Clunch Pit (see 41).
Parish ponds at Lolworth and at Boxworth.
The small outlier between Long Stanton and Over is cut off at its southern end by the railway; the section shows several feet of gravelly Boulder Clay resting irregularly on Oxford Clay. There are here some large ice-marked boulders, two about 3×3×2 feet.

North of the Ouse River.

Railway cutting S.W. of Bluntisham. Shows a scoop of gravelly Boulder Clay at its east end, a continuation, at a much lower level, of that which caps the ridge to the west.
The Boulder Clay north of St. Ives is so like the Oxford Clay on which it rests that it is difficult to distinguish between them, except in good sections.
In the large railway cutting between St. Ives and Somersham the Boulder Clay is a bluish-grey clay (perhaps rather lighter in colour than Oxford Clay), enclosing boulders of chalk, flint, and other rocks. The ridge is capped by this clay with considerable regularity, and on it are scattered patches (some being mere remnants) of gravel at a considerable height, certainly not less than 100 feet above the fen lands.

It will be well to note here the varying heights at which the Boulder Clay rests on the older formations, and see if these apparently irregular variations have any definite relation to each other; and if so what conclusions may be drawn from them.

Taking first the edge of the main body of the clay, where it winds along the summit of the Chalk escarpment, we find that east of Tharfield its base is about 530 feet above the sea; this height (and the remark applies to all which follow) being an approximation to the truth; few Ordnance levels are given in the district, some of the heights have been taken by aneroid, and in other cases allowance has to be made for the estimated thickness of the deposits; but any error there may be is too small to greatly affect the general question. The surface on which the clay rests falls slowly, almost imperceptibly, eastwards until it crosses the section line at Barrington Hill at a height of 300 feet. It is the same at the windmill west of Horseheath, but it rises again in the direction of Balsham, where it would be about 350 feet, whence it again falls slowly in the direction of Dullingham, being about 240 feet E. of Newmarket, and the depression is probably continued further.

For the present this may be considered as an even line (with occasional local depressions, the base of the clay quickly returning to its normal elevation), not level, but sloping gradually to the north-east in the direction of the Chalk escarpment. The fall is 180 feet in 18 miles, or only 10 feet in a mile, a proportionate incline of 1 in 528, equal to an angle of little more than 0° 6′.

But we find the clay more rapidly descending, from the 'scarp, in a generally transverse direction, probably to south and east as well as to north and west; but with the latter only are we at present concerned. Starting from the highest point (530 feet) by Tharfield, and going in the direction of Cambridge, we cross three small outliers of Boulder Clay at successively lower elevations, the distances apart and the relative levels being as follows:—

Successive Distances.	Fall in Feet.	Angle.	Proportionate Incline.
1 mile - - - -	80	Nearly 1°	1 in 66.
$\frac{7}{8}$ „ - - - -	80	1°	1 in 57.
$1\frac{3}{4}$ „ - - - -	15	0° 6′	1 in 600.

These data give a uniclinal curve corresponding with the form of the old surface on which the clay was deposited, its steepest part, about $1\frac{1}{4}$ miles from the present scarp line, being inclined rather more than a degree (see Fig. 14, p. 77).

Again, at Barrington Hill the base of the clay is 300 feet above the sea, and it descends thence by Hildersham and Abington nearly to the bottom of the valley at Babraham.

———	Distances.	Fall in Feet.	Angle.	Proportionate Incline.
From the S.E. to the N.W. boundary of the patch on Barrington Hill - - -	$1\frac{1}{2}$ miles	155	1° 9′	= 1 in 50
From the N.W. boundary to the base of patch at Babraham - - -	$2\frac{1}{2}$ „	60	0° 15′	= 1 in 220

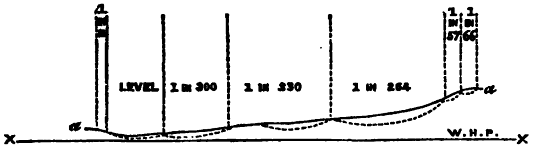
It is seen here also that the sharpest slope is somewhat in advance of the escarpment. The general slope of the base of the clay is obtained from the following data, referring to a line drawn through the outliers of the first table, in a direction nearly north across the Orwell Ridge, and through the small outlier between Long Stanton and Over to another ridge north of St. Ives.

——	Successive Distances.	Fall in Feet.	Angle.	Proportionate Incline.
No. 1 Outlier	1 mile	80·	Nearly 1°	1 in 66
No. 2 „	$\frac{7}{8}$ „	80·	1°	1 in 57
Orwell Maypole	$7\frac{1}{4}$ „	145·	0° 13′	1 in 264
Dry Drayton (boundary)	$6\frac{1}{2}$ „	105·	0° 10′	1 in 330
Outlier between Long Stanton and Over	4 „	70·	0° 11′	1 in 300

From this last point to another south of Bluntisham, $3\frac{1}{2}$ miles across the Ouse valley, a line joining the base of the clay at the two places would be nearly level; it then *rises* at least 30 feet in half a mile to the summit of the ridge, that is at an angle of 36′, equal to a proportionate incline of not less than 1 in 88. A small outlying patch of the clay at Burleigh Hill Farm, somewhat off the line, but still between St. Ives and the ridge to the north, occupies ground at an intermediate level, thus conforming to the general lie of the base of the clay as determined by a consideration of the various levels.

It will be seen from the above that the small outlier between Stanton and Over, now a mere remnant, occupies the lowest point, or thereabouts, from which the base of the clay rises in each direction. This rise is not great, but it is constant, and for the area in which it occurs appreciable; we are not dealing with a hilly district, a fact which makes observations of this kind the more difficult, but none the less valuable or suggestive. The diagram, Fig. 14, has been constructed from the above data, and shows the original base of the clay along the line described, which may be taken to represent generally the contour of the surface from the escarpment to the fens at the time of the deposition of the Boulder Clay.*

Figure 14.—*Diagram Section showing the slope of the Boulder Clay.*



The dotted line shows the present surface.
The line *a a* shows the original base of the Boulder Clay; * * Sea-level.

From the form of the old surface on which the Boulder Clay rests, determined by these heights and the lines connecting them, we learn

* See also, Physical Geology of East Anglia during the Glacial Period. W. H. Penning, *Quart. Jour. Geol. Soc.*, vol. xxxii. p. 198.

that the Cambridge Valley, as such, is Pre-glacial, or at all events that it existed very much in its present form before the Boulder Clay was deposited. The main line of drainage was, as now, that of the Ouse, a fact primarily owing to the more rapid erosion of the beds along the anticlinal line, as previously suggested (p. 6).

It is not asserted that the clay rests on a perfectly even surface; it is indeed locally uneven, but its general slope is as indicated, the accuracy of the line between the selected points being borne out by intermediate heights and by the manner in which the boundary follows the contour. There are many slight hollows or channels, and wherever the clay runs out in a narrow tongue it may safely be assumed to occupy such a hollow; examples occur east of Conington, at Dry Drayton, and at Comberton, while a more striking instance is the long narrow strip which caps the ridge of the Orwell Chalk outlier.

There are other and still more important channels in the old surface under consideration; one is partly along a small valley which runs from near Balsham to Hildersham, and is partly shown in the section, Plate 6.

Three miles south from Barrington Hill along this section line we find the clay only 160 feet above the sea, and at Babraham it is only 105. Between these points, that is east of Abington, its base is about 120 feet, and the patch of Boulder Clay at this place rests not on a level surface, but against the flank of the chalk hill. The position on the slope, and at a lower level than the main spread of clay, together with the gradual fall in one direction, bears testimony to the fact of the scarp at this point having been cut through by an old valley, nearly along the present line of the Bourn River, which was filled by Boulder Clay and has since been re-excavated.

A similar set of circumstances occurs about Chesterford; a depression in the normal base line of the clay along the escarpment, and some small patches of clay in the valley, indicating the existence of an old valley through the escarpment. These are the only two cases within the district, and the conclusions derived from them are in both instances borne out in a remarkable manner by additional and similar evidence. In the valley along the line of section (Plate 6) a thin bed of gravel occurs beneath the Boulder Clay (see p. 73); and a little further north by Bartlow is another patch of gravel, hitherto considered of doubtful age, which on this hypothesis might be older than the Boulder Clay. In the Chesterford Valley is a bed of loam contorted and devoid of fossils, possibly passing in under Boulder Clay, and perhaps referable to the same period as the above. The large patch of gravel south of Whittlesford rests on a chalk slope, thinning out against the higher ground, and is probably of the same age as the Chesterford loam. Both this gravel and that at Bartlow present lines of bedding which dip at a high angle, both are unfossiliferous, and resemble somewhat in these and other respects the known "Middle Glacial" beds on the south of the Chalk range. The presence within this area of gravels differing from all the others may be due to an extension of the southern gravels *along the lines of the old valleys*, where they would form a basement bed to the Boulder Clay.

On the other hand, in the absence of evidence from superposition, it is possible that these three patches at Bartlow, Chester-

ford, and Whittlesford may be newer than the Boulder Clay, and belong to the old river series hereafter described (p. 85).

MARINE GRAVELS AND LOAM.

This series, which is of late Glacial or very early Post-glacial age, occurs in small patches, single or in groups, of loam containing stones of various sizes and description, or of loamy gravel. The loam is not often good enough or in sufficient quantity to be useful for brickmaking, although some pits in it are worked for that purpose, neither is the gravel of good quality, requiring to be sifted and sorted to render it available for road-mending.

These remnants of what must formerly have been an extensive, if a thin, deposit generally occur in lines, and thus seem to have some definite relation to each other. They occur generally on the table lands and higher grounds, and probably occupy old depressions or channels in the rock beneath, having thus been somewhat preserved from denudation.

The section (Plate 6) traverses a line of these patches of gravel, commencing on one of them at Ashdon. From this point they rise gradually to the top of Barrington Hill, then fall towards the old line of valley previously described (p. 78) to their lowest point E. of Babraham—resting on Boulder Clay with one partial exception. From this spot they lie on the Chalk, and rise gradually to the summit of the Gog-Magog Hills at Vandlebury.

It is but right to state that our colleague Mr. WHITAKER, who has seen these gravels with us, does not altogether agree with our classification. He writes to us: "I think that some of these gravels may be older than the Boulder Clay, rather than of late Glacial or of Post-glacial age, for the clay that sometimes occurs in thin patches on them seems to me to be Boulder Clay weathered in place, and not reconstructed, being exactly like what results from such weathering in other districts. For instance, in the pits on the northern side of the road a quarter of a mile W.S.W. of Bishop's Charity Farm, on the hill southwards of Cherry Hinton, there is what seems to me to be weathered sandy Boulder Clay above the gravel."

The pits at Ashdon are in rough chalky gravel, false bedded, and in one case with a black band (? manganese peroxide) at the bottom, from 6 to 8 feet being shown.

Barrington Hill is covered by Boulder Clay, which towards the top includes a thin bed of laminated loam, shown in the road cutting about three-quarters of the way up the hill from Linton. The hill is capped by coarse brown gravel (as seen in a pit 6 feet deep in 1874, but since filled in) with large stones and some quartz-pebbles. Other patches to the W. and N. occur at a lower level. The Boulder Clay forms almost an outlier, being united to the main spread only by a narrow neck on the eastern side.

In the patch to the north the junction of gravel over the clay was obtained by digging in the slope of the road cutting about a furlong N.E. of the small Chalk inlier exposed by denudation of the Boulder Clay.

There is a spring at the N. end of the large patch of gravel E. of Hildersham, the water of which is thrown out by the clay, in an hollow on the surface of which the gravel rests. Beyond this the gravel overlaps the Boulder Clay and rests on the Chalk, the junction being exposed in the cutting at the cross roads. There is an old gravel or sand pit just N. of the "*l*" in "Hildersham," but the section is now overgrown, and at the W. end of the patch is an old "Sand Pit," also overgrown, marked on the Ordnance map.

By the junction of roads a quarter of a mile N. of Hildersham Church there is an exposure of 10 feet of stiff grey Boulder Clay, with a lenticular patch of sandy loam at the bottom, and on the top a pocket of sandy gravel, probable once connected with that which now caps the hill above.

At Clay-pit Plantation the gravel appears to lie above the Boulder Clay, but the section is completely grown over. The Gravel pit on the hill, a quarter of a mile N. (on the line of section), showed 8 feet of compact angular flint gravel, stained dark brown, and with a thin interbedded band of brown sand. The road-cutting 3 furlongs S.W. is in sand, with flints and chalky gravel in very confused beds to a depth of 7 or 8 feet, and there is an old gravel pit in the plantation near by.

The pit a quarter of a mile N.W. of Little Abington Grange is in coarse confused gravel, mainly composed of large flints and chalk pebbles set at all angles, Cambridge coprolites, and red chalk, with pieces of septaria, quartzites, and other rocks.

The cutting on the Newmarket Road, by the 50th milestone from London, just W. of the above section, shows Boulder Clay capped by about 2 feet of coarse gravel, consisting of stones derived from the Boulder Clay impacted in a reddish sandy clay.

Signal Hill, to the N.W. of the above, is apparently capped by gravel, but no section was seen. On the hill to the northward, however, gravel is again found, though the pits two furlongs N.W. of Worsted Lodge are partly grown over; a new excavation showed 6 feet of gravel, consisting of chalk stones, stained yellow outside and packed close together, with hardly 5 per cent. of other stones; the top 2 feet had, however, some flints in a more sandy matrix. Another hole showed the following deposits:—

	Feet.
Irregularly bedded sand and gravel - - -	3
Very chalky gravel - - - - - -	3
Grey sand - - - - - - -	1

The other end of this outlier had also been excavated, and the gravel there apparently contained more flints.

The gravel pits N. of Fulbourn Lodge gave the section below:—

> Sand and chalky gravel under the edge near the entrance, passing towards the top of the hill into 3 feet of chalk-rubble and sandy clay, 6–8 feet.
>
> Bedded white chalk, 10–12 feet.

A small pit at the E. end of the same outlier showed a foot of yellow laminated loam over 2 feet of fine gravel, consisting of chalk and flint pebbles.

Copley Hill, Misleton Hill, and Little Trees Hill are capped by similar gravel.

The old pits, half a mile W. of Hill's Farm, are well known, and have been described by Prof. Sedgwick and other geologists. The beds exposed here in 1875 were as follows:—

> Stiff yellowish sandy clay, containing stones of various sizes and set at various inclinations; the pebbles of chalk are rounded, the others angular. About 50 per cent. are chalk, 30 per cent. flints, and 20 per cent. of various other rocks, 6 feet.
>
> Coarse rubbly gravel, said to have been obtained from below this, and resting on Chalk, 3 to 4 feet.

On Steeple Hill, north of Shelford, there is a patch too small to be mapped, being merely a pocket of coarse gravel at the top of the clunch pits. This is probably the bottom of a long pipe that descended through beds of chalk since removed by denudation, and thus is far below the level at which the base of these gravels once extended over this ground, being nearly 100 feet lower than the summit of the Gog-Magog Hills.

There are other patches of similar gravels to the N. and E. of the section line, resting on remnants of a surface gradually sloping from the highest points of the escarpment down towards Newmarket. An elevated spot E. of Balsham is covered by a thin patch of gravel, in which were no sections. Between this and Barrington Hill a tiny patch remains, and there are traces of another just S.W. of West Wratting.

A mile S.E. of Westley Waterless, and on high ground, is a patch of loam only a few feet thick, and thinning out all round to a mere loamy soil. It is exposed in a brickyard at Brinkley near its southern end; at the northern end also is an old brickyard.

Many patches of Gravel on the Chalk ridges are too small to be mapped; they make no feature, being in old channels, and can be seen only when cut through.

There is a small patch of loam on the Boulder Clay, on the top of the escarpment E. of Tharfield, about 500 feet above the sea; it may be seen in section at the brickyard. (See Memoir on Sheet 47, p. 64.)

A small patch of yellow gravel, 1½ to 2 feet thick, occurs on the higher part of the Boulder Clay at Elsworth Common, about 8 miles westward of Cambridge; it contains large pieces of a siliceous rock which is found also in the upper part of the Boulder Clay.

A similar series of gravels to that on the Barrington and Gog-Magog Hills caps the ridge of Boulder Clay, which rises to N.W. of the Ouse valley from Bluntisham. The spring half a mile W. of that village is thrown out by the Boulder Clay beneath a chalky gravel; there is a small pit in this gravel S.E. of the mill, and another in the small patch to the E. The little patch half a mile W. is not now seen in section; indeed, it seems to have been nearly all dug over and carried away.

A quarter of a mile N. of the mill is a small pit in the larger patch showing about 3 feet of rolled chalky gravel and Oolitic débris; this is again seen in section a few chains to the north. Along the top of the ridge to the W. are many small unmappable patches of gravel and gravelly soil; and at Wood Hurst is a long narrow strip of gravel and yellow loam seen only in one section, but giving ample evidence of its existence and extent.

Another spur of this higher range of the Boulder Clay, a mile S.E. of Pidley, is flanked and just overlapped by a small patch of gravel and sand. There were gravel pits here at some time, but they have been long abandoned, and no section is visible. A minute patch of gravel or sand still remains on the summit of an elevation S. of Somersham, and about Warboys, on the high ground in the N.W. corner of the map (Plate 7), are patches of gravel, now so thin, however, that they might more properly be called a gravelly soil.

The above sections show that this series of gravels consists of materials such as would have been derived from the waste of Boulder Clay—chalk, flints, oolites, and boulders of rocks of many kinds. It will be observed also that in many of the pits the chalk pebbles are seen to be rounded, while those of other rocks are frequently sub-angular; but the quartzites and similar stones derived from a long distance are generally waterworn.

CHAPTER VIII.—POST-GLACIAL DRIFT.

GRAVELS OF THE ANCIENT RIVER SYSTEM.

The valleys which run northwards and north-westwards from the chalk escarpment contain some very interesting relics of early river deposits, which remained unnoticed and undescribed until we commenced our survey of the district. In 1861 Prof. SEDGWICK commented on the supposed absence of such beds from the higher coombs and hollows of the Chalk escarpment, coming to the conclusion that these valleys had been swept out by the action of "rapidly descending water floods," rather than "by a long continued and slow process of erosion." If Prof. SEDGWICK had known of the existence of beds of gravel in such valleys he would probably have been the first to modify his opinion, as he was the first to reduce the drift deposits of Cambridgeshire into something like order.

Such patches of these gravels as afterwards became known were probably regarded as forming part of the series last described; it is indeed even now very difficult to separate the higher portions of these old river gravels from those of earlier date, the two being much alike in character and composition. The latter, however, generally occur as outliers on the higher ground, and though they occasionally descend into hollows they do not appear to conform in any way to the direction of the old or present valleys.

On the other hand these early river gravels are elongated in the direction of the long but now dry valleys which run from the Chalk Hills, and they are found at intervals along the sides of those valleys, so as to present series which descend gradually to lower levels. The patches, moreover, are larger at lower levels, and those from several valleys tend to concentrate at the points of junction, so that at last they stream out to form long-continued gravel-capped ridges which trend more or less in the direction of Cambridge.

It was only after they had nearly all been mapped that the true character of these ancient river deposits came to be understood, and in 1875 one of us showed that they might be referred "to the existence of an ancient river running, as does the present one, along the foot of the escarpment, although, of course, not on the ground occupied by the Cam of our own time. Reasons were given for this conclusion, and for the proposition that "we have here a series of *river gravel* terraces occuring at all heights, from nearly the bottom of the present valley up almost to the top of the Chalk escarpment."*

The great age of these gravels is shown by their general relations to the principal features of the country; they are not only for the most part at a distance from the present river, but their lines of

* W. H. PENNING, *Quart. Journ. Geol. Soc.*, vol. xxxii. p. 200 (1876). See also "The Post-Tertiary Deposits of Cambridgeshire," by A. J. JUKES-BROWNE, Cambridge, 1878, p. 46.

direction are different from, and sometimes transverse to those of the latter. They fill old channels, which must have been low ground when these gravels were deposited, though now often the highest in the neighbourhood. Their fluviatile origin is proved by their connexion with the upland valleys, and by the occasional occurrence of land and fresh water shells and mammalian remains.

The most westerly series of these gravels begins in Wardington Bottom, a deep coomb-like valley described as having received its initial form and its commencement from the flexure in the Chalk S. of Royston (see p. 67). It is bounded on the S. and E. by the highest part of the Chalk escarpment, on the W. and N.W. by elevated ridges, here and there capped by patches, as the scarp is by the mass, of the Boulder Clay. Its sides are steep, and descend in a distance of about a mile at least 300 feet, and it forms altogether an amphitheatre of Chalk, into which project descending and converging tongues, with minor coombs between. But it is virtually a dry valley, the small channels that occupy the bottom being without water for a greater part of the year.

Half a mile west of the "W" in "Wardington" is a small patch of the gravel, which occupies the high ground between two small channels that unite just below. A large patch remains S. of Knowns Folly, and a wash from this extends down to the low ground, and between the gravel and the wash there is no definite line of division. A minute patch occurs on the higher ground half a mile east, and North Hall stands on a much larger one.

Some notes of the pits in these outliers have been given in the memoir on sheet 47, p. 71, but the localities have since been revisited and additional information obtained.

At North Hall the pit near the house is about 9 feet deep in chalky gravel with seams of sand, and boulders of quartzite, basalt and other rocks. A newer excavation by the roadside east of the farm shows a similar section, and the workmen said large bones were often found.

At the pit north of Sharpens the following section was seen in 1878:—

	Feet.
Fine chalky gravel - - - - - -	2
Brown laminated loam - - - - - -	1
Gravel of small flint and chalk pebbles, with occasional layers of fine sand - - - - - -	6

In another place the layers were bent down so as to dip northwards at an angle of about 20°.

These patches of gravel are on ground considerably above the present water-course, and gradually leave its direction, that at Sharpens being half a mile away; another patch N.E. of Heydon Grange, in which no pit occurs, is at the same level and at a still greater distance. The ground to the N. and N.E. of this is covered with a sandy and flinty soil, which leads on to a large outspread of gravel and sand; this is important from its size relatively to the others, from its forming a distinct and prominent ridge in the midst of a Chalk plain, from its continuing its direction, while the existing stream bends away at right angles, and from its yielding remains which testify to the mode of its formation. It extends for upwards of 2 miles from the road N.W. of Chrishall Grange in a N.N.E. direction by Crowley Hills to a point S.E. of Triplow. It is about half a mile broad; but its southern half consists mainly of sand, and its boundary at that part cannot be accurately defined, for the sand has come down over the Chalk slope in every direction, giving rise to a sandy soil greatly resembling that on the sand itself, and sections (even in ditches) are entirely wanting.

The northern end of this long ridge consists of gravel, and is much more clearly defined, although it also gives rise to a sandy soil on its western side. It may be noted here that under certain circumstances, for instance in the summer season when the ground is covered with crops, it is almost impossible to say where these gravels actually end. Both the Gravels and the Chalk on which

they rest are so highly absorbent of moisture that ditches are needless, ponds are useless, draining is not required; therefore when no pits occur one has to depend for evidence upon surface indication. The gravels cap the ridges, and of course the material of which they are composed, works down the slopes, and overlaps the actual boundary.

Although this patch of gravel now forms an elevated ridge throughout, it doubtless occupies an old hollow in the Chalk, trending N.E. in the direction of Whittlesford. The base of the gravel is not level at its northern end, the boundary on the Triplow side being much higher than that on the other, showing that this part is banked against a sloping surface, or rather occupies a hollow in the sloping surface of the chalk.

A pit W. of the track from the high road to Duxford Grange gave this section:—

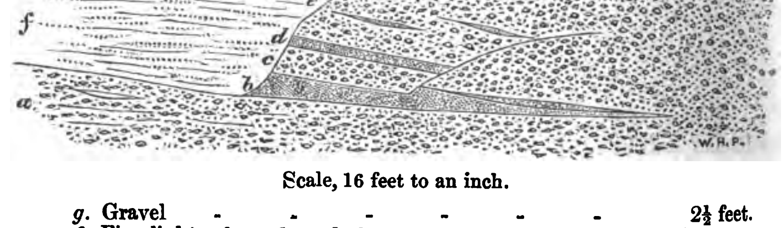
Coarse Chalky gravel, roughly stratified, nearly all flints, not much rolled, with a small intercalated patch of loam containing shells—*Succinea Pupa,* &c. - - - -	8 feet.
Fine chalky sand - - - - - - -	1 foot.
Gravel entirely composed of small chalk stones - - -	1 foot.
Fine sand.	

There is a smaller patch of similar sand E. of the Grange, which from its direction seems to indicate the incoming at this point of another line of gravels, of which this is the only remnant. The sandy or loamy nature of the deposit in this patch, and at the southern end of the large one, would also seen to bear out the idea of a junction of streams at this point.

Another patch of gravel is seen on the E. side of the main one, from which it is separated by a narrow band of Chalk, exposed by denudation along the lower ground occupied by the road N. from Chrishall Grange. A pit at the N. end shows a foot of sand over 2 feet of chalky gravel resting on Chalk.

About a mile north-east another large patch of gravel and loam commences, and is a mile and quarter long and three-quarters of a mile wide. This also rests on a sloping surface of chalk, the boundary of its western end being on high ground, that of its eastern side 20 to 30 feet lower, in the valley by Whittlesford Railway Station. There is, as before stated (p. 79), some doubt about the age of part of this gravel; but we believe that whether the gravel at its southern end be of Glacial date or not, some of it belongs to the ancient river series. The gravel as seen in two pits west of the station is much contorted, still we think this feature quite compatible with the conditions under which the ancient river series was formed (see p. 123). It will be seen that in the pit noted below, and shown in Fig. 15, a pre-existing bed of gravel has been scooped out, and the part so excavated afterwards occupied by loam, gravel again coming on above. We consider that the loam and the overlying gravel are a part of the series now under consideration.

Fig. 15—.*Section in the Gravel Pit on the south side of road a few chains west of Whittlesford Railway Station.*



Scale, 16 feet to an inch.

g. Gravel - - - - - - -		2½ feet.
f. Fine light-coloured sandy loam - - -		12 „
e. Gravel and sand - - - - - -	}	
d. False-bedded sand - - - - - -	}	
c. Gravel - - - - - - -	}	about 15 „
b. False-bedded sand - - - - - -	}	
a. Gravel, excavated to a depth of - - -		7 „

A few yards nearer the station than the part shown in the figure is a small cave, scooped in gravel; the roof of which is formed by the under-surface of a loam (probably=f.) dipping north about 15°.

A gravel pit just S.W. was about 10 feet deep in gravel, with contorted loam and layers of sand.

At the brick yard, on the north side of road, about a third of a mile west of the railway station, the pit is in finely laminated sandy loam, grey at the bottom, weathered buff towards the top; dug to a depth of 20 feet, from the lower part a broken specimen of *Cardium edule* was taken.

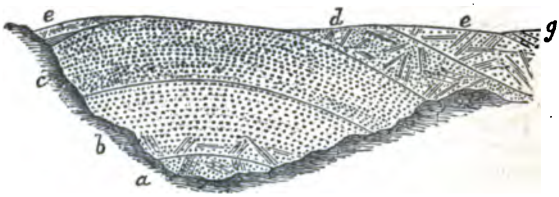
A pit, half a mile N.W. of the railway station, showed 20 feet of coarse roughly stratified gravel cut off on the south by a grey sandy loam, probably the northern edge of the same bed as that seen in the brickyard, and in the gravel pit, Fig. 15, where the loam cuts out the gravel in a similar manner.

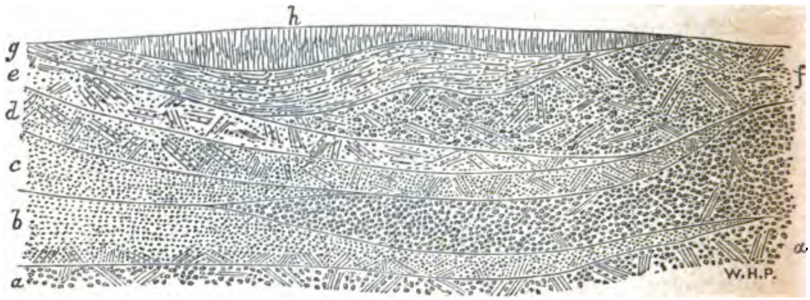
The gravel just S.W. of Bartlow, which is of doubtful age (see p. 78), seems to us to be referable to these ancient river gravels. For details see Memoir on Sheet 47, p. 72. Between this and Whittlesford are several other patches at about the same level, and these we conceive to be remnants of the same series, representing an old river-line from Ashdon by Bartlow, Linton, and Pampisford Hall, joining that from Wardington Bottom at or near Whittlesford. The united streams turned thence northwards, and although no more traces of similar deposits are now found it is owing to the fact that no ground high enough to reach their level remains on this side of Cambridge; the old line must have passed somewhere through the gap formed by the Gog-Magog Hills on the one hand and by the Barton and Madingley ridges on the other. There is a very small patch of gravel still remaining on the top of Redland Hill, near Harston Station, which is probably the last remaining trace of another tributary of the old river, but except the ridge itself, which points by Maggots Mount towards Shelford, there is nothing to indicate its direction.

Another drainage system appears to have been contemporaneous with those just described, and to show that the two great streams thus produced met somewhere in the neighbourhood of Cambridge. The tributaries of this second river descended from the hill-slopes about Balsham and Brinkley on the other side of the watershed formed by the Gog-Magog Hills and the high ground by Abington, Balsham, and West Wickham. From these high lands several long dry valleys converge towards the N. and N.W.

The westernmost of these commences south of Balsham, near New Yole Farm, and trends to the N.W. About half a mile W.S.W. of Balsham limekilns a very small patch of gravel occurs just on the brow of the hill, probably occupying a hollow in the chalk. A little further down, and on the opposite side of the valley, some gravel pits have been marked on the map; these are in an elongated patch of gravel, sand, and loam, and exhibit a section that is somewhat peculiar from the rapid thinning out of several beds, and from an anticlinal curvature along an axis parallel with the direction of the valley (see Figures 16, 17). The loams and sands show that there must have been quiet reaches in the rivers by which these beds were formed. The saddle-back was probably caused by a gradual dissolving or washing away of the chalk on either side of the gravel, which now occupies a ridge, but must have been on a flat or in a channel at the time of its deposition. The northern end of the patch is almost all yellow loam.

Figs. 16, 17.—*Sections in Gravel Pit 2 miles W. of Balsham.*





(Scale, 16 feet to an inch.)

h. Soil.
g. Grey loam.
f. False-bedded sand and gravel.
e. White false-bedded sand.
d. Yellow false-bedded sand.
c. „ finely bedded sand.
b. „ sand, false-bedded at bottom.
a. Fine false-bedded gravel.

The gravel of the Balsham pits does not occupy the highest ground, but it rests on the western flank of a deep valley, which runs between two outliers of Boulder Clay, and its western side abuts against, and partly rests upon, a smaller patch of that clay.

A space of a mile and half intervenes between this remnant of gravel and the next in the same series, which occupies the summit of a minor elevation, just N.W. of Dungate Farm, situated on the line of the Balsham Ditch, where the pits show 6 or 8 feet of chalky and somewhat clayey gravel, with patches of sand; the material is made up apparently of waste from Boulder Clay, and contains many pebbles of hard and soft chalk, flints, mostly angular, quartzites, and fragments of other rocks. In places a red-brown sand occurs on the top, many of the flints below being deeply stained thereby.

North of this there is a much larger mass which rests partly on the flank of the hill west of Wratting Valley Farm, the western boundary being at a higher level than the eastern. Its northern end, however, runs out as a spur, pointing directly to the south-eastern end of the gravel-ridge near Great Wilbraham.

The pit by the side of the road, about 1¼ miles S.S.E. from Great Wilbraham, shows 6 to 8 feet of hard chalky sand with scattered flints, but very few chalk stones; the upper part is more sandy from the dissolving away of the chalk grains, leaving the flints embedded in a brown sandy soil. Below are pockets of light-coloured sand full of flints descending into the Chalk.

A small excavation about a quarter of a mile northward was 8 to 10 feet deep in coarse flint-gravel, the stones being closely compacted and set in a matrix of chalky sand, most of them having their long axis vertical; a few lenticular patches of sand gave a rough appearance of bedding.

The railway cutting shows 6 feet of whitish chalky sand, full of angular unrolled flint fragments, with the faces of cracked pieces sometimes coated by Carbonate of Lime, and a few chalk pebbles. Thence the ridge continues in the direction of Great Wilbraham.

To the east of the line just described there are two other valleys which run north-westward from the slopes about West Wratting and Weston Colville, in 51 S.E., and both of these contain a similar series of gravels. As before, they commence with small outlying patches in the hollow of the present valley, farther down larger outliers occur high up on its slopes, till eventually they desert the existing line of drainage and are continued along the ridge which separates the two valleys at Six Mile Bottom. This ridge is prolonged for upwards of four miles in the direction of Wilbraham and Quy-cum-Stow, and forms a remarkable feature indicating the enormous amount of denudation (or as we should prefer to say *detrition* and *devection* of material) which must have taken place since the deposition of these gravels. How great must be their antiquity, when the valley-bottom along which the ancient river ran is now an elevated ridge from 30 to 40 feet above the ground on either side.

In the first of the above-mentioned valleys the highest patch is merely a speck on the map, nearly a mile north of Balsham Church.

For some distance further down the valley all traces of the old gravels seem to have been destroyed, but at a point about a quarter of a mile N.E. of Wadley Hall, and on the slope of the spur made by the junction of a tributary with the main valley, there is another patch, too small to be shown on the map; it fills a hollow, and here many mammalian bones were obtained, some of them being now in the Woodwardian Museum at Cambridge. (See list, p. 106.)

On the slope N.W. of Lark's Hall a larger patch of sandy gravel occurs, from which also bones are said to have been obtained.

Half a mile northward another outlier lies on the flank of a ridge extending toward the railway, and the end of which appears to be capped by a small patch of similar material.

In the second valley from Weston Colville, only two or three small patches of gravel have been found, the first being a narrow capping to the ridge, about a quarter of a mile S.W. of Carleton Grange, with some old pits, now ploughed over, several feet in depth. A tiny remnant occurs just N.W., and a sandy soil in the only sign of a similar deposit on the ridge east of Lark's Hall.

There is a pit in the small patch by the road, a mile S.E. of Six Mile Bottom Station, which shows 4 feet of gravel, made up almost entirely of flints and chalk pebbles.

On the opposite side of the valley is a more extensive gravel-covered area, forming a ridge, the northern end of which is cut through by the railways a short distance east of Six Mile Bottom Station. A small gravel pit was open in 1875 in the fields about half a mile east of the station, showing 6 or 8 feet of gravel and sandy loam.

The railway cutting shows 6 or 8 feet of sandy gravel, the matrix being a hard compacted yellowish-white sand, in which are scattered flints of all sizes, many being unrolled and fresh from the Chalk; no chalk-pebbles, and only a few brown quartzites. The bottom is obscure, but seems to be in chalk.

This spread was probably formed at the confluence of the two tributary streams, the course of which we have just been following.

Some other patches of sandy gravel are also found to the northward, by Westley Lodge and Six Mile Bottom, which are at a much lower level, and probably illustrate a later stage in the erosion and formation of the present valley.

Beyond the railway the high ridge which trends north-west is also capped by gravel, but no sections were seen; this patch terminates by the "*Tumuli*" east of Great Wilbraham, and Chalk comes to the surface about the cross roads near by.

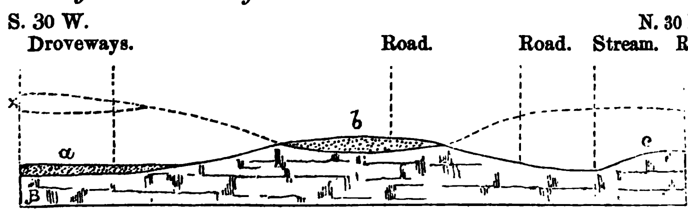
Gravel, however, again sets in to the north-west and continues for more than three miles along the ridge, often with a width of half a mile. Several pits just above the word "Temple" exhibited about 9 feet of irregularly bedded gravel and sand, some layers of the former being very coarse and

chiefly composed of flints; a molar of *Equus fossilis* was obtained here, and the workman said that bones were frequently found. In the hollow by the wood on the west there is a small pit exposing 5 or 6 feet of clean fine laminated sand, with some intermixture of chalky matter, but without any trace of gravel.

We think it probable that this deposit of sand was formed in a back-water produced by the incoming of the river from the south, the course of which has been already described and its gravels noted as last seen in the railway cutting S.E. of Great Wilbraham (see p. 86). This appears to have been the last tributary of the river which thence flowed onward to the N.W., and has left such a remarkable memorial of itself in the long ridge which extends in that direction.

Fig. 18 is a section across this ridge, showing its relation to the lower ground on either side.

Fig. 18.—*Section from Wilbraham Fen to Bottisham.*



Horizontal Scale, 2 inches to a mile. Vertical scale, 200 feet to an inch.

a. Newer Gravel. *b.* Gravel of Old River Series. *c.* Chalk.

The dotted lines indicate the former outline of the ground at the time of the formations of the Gravels *b*, with the probable edge of the Boulder Clay at x.

The large gravel-pit by the roadside just north of Little Wilbraham Church was 6 to 8 feet deep in sandy loam over compact chalky sand with flints. Another hole in the same pit was dug in a hard loamy sand, and in this were found very small specimens of *Succinea*, and also a minute *Pisidium* or *Cyclas*

Gravel holes some 6 feet deep in a field about a third of a mile north of Frog End, gave the following section:—

Loamy soil.
Sandy and loamy marl with shells (*Succinea putris* var. *minor*, *Helix*, small sp., *Pupa marginata*.
Coarse flint-gravel in sandy matrix.

Some pits by the side of the road a quarter of a mile N.N.W. are in 8 feet of gravel with sandy beds and patches; at the bottom the workmen had found bones.

Gravel has been obtained from several places south of Quy-cum-Stow, and one old pit is still distinctly marked near the Church.

Beyond this point the continuity of the ridge is broken by the gap which the Quy water or Wilbraham river has made in escaping from Wilbraham Fen, but the ground westward is capped with loam and gravelly soil.

This small patch is cut off by another hollow draining into High Ditch Lane, but westward by Greenhouse Farm gravel and sand again cover the high ground, along which the main road runs. The behaviour of the gravel was clearly seen in a ditch running south from the road near the old turnpike, gravel being shown bedded up against clunch which forms the southern slope.

Where the road to Fen Ditton branches out from the Newmarket Road there is an old gravel pit now planted with trees, which we were informed exhibited about 10 feet of loam and sand, with a bed of fine gravel at the bottom. Gravel has also been dug in the fields to the S.W., but it thins out as the slope falls to the west, and the whole series is cut through by the present valley of the Cam.

If a line be drawn prolonging the direction of these gravels across the valley it will strike and follow that of the long ridge of Chalk Marl upon which stood the Roman town of *Camboritum*; on this outlier of Chalk Marl gravelly soil, with descending pipes of the same material, was noticed when the fields west of the Almshouses were dug for coprolites.

A small patch of gravel was mapped about half a mile to the N.E. near a farm, where a gravel pit showed the following section in 1875:—

	Feet.
Brown gravelly soil - - - -	2
Chalky sand with a few small flints - -	4
Flint gravel set in a matrix of chalky sand, coarser near the bottom - - - -	4

This gravel lies in a hollow on another small outlier of Chalk Marl, against the eastern side of which beds of loam and sand are banked belonging to a newer series of river deposits, but probably formed to a great extent out of the older beds of gravel and sand, and the underlying clunch.

It is worthy of special notice that the gravel of Gravel Hill, on which the Cambridge Observatory is built, lies banked up against the S.W. side of the Chalk Marl ridge above-mentioned. This was clearly shown in 1873 by the workings for coprolites in the fields north of the Observatory. The ground where the gravel thinned out is about 80 feet above sea level, but in the large pits near the farm, the base of the gravel is about 18 or 20 feet lower.

A large gravel pit near Gravel Hill Farm, now grown over, gave the following section in 1875:—

	Feet.
Gravel interrupted and disturbed by pockets filled with contorted brown sand and occasional flints, with films of carbonate of lime lining the bottom. This is probably due to the dissolving away of the numerous chalk pebbles - - - - - -	6
Fine gravel, rather irregularly bedded, consisting of nearly 50 per cent. of chalk pebbles, the rest flint, with a few hornstones, quartzites, &c., one large boulder evidently derived from the neighbouring Boulder Clay - - - - - -	6

Professor SEELEY states that he found shells "in the gravel under the Observatory,"* and there is a flint flake in the Woodwardian Museum which is said to have been found in gravel near this place.†

We have here a repetition of the phenomena noted near Great Wilbraham, where we concluded that a tributary from the south entered the main river, and we think, therefore, that there are strong grounds for supposing this to be the point where the great stream from the southern valleys joined its current to that coming from the east. It will be remembered that we could not follow the course of the former much beyond Whittlesford and the ridge by Stanmoor Hall, but that we supposed it to have been continued in a northerly direction, which would naturally bring it near the point we have indicated as being the junction of these two early Post-glacial rivers.

The stream from the south was, moreover, likely to be the more powerful, from its greater length and wider basin of drainage. We should therefore expect that its current would prevail over that of the more easterly stream, and give a northerly direction to the river which resulted from their union. This is precisely what appears to have happened, for a long ridge thickly capped with gravel extends from this point in a direction N.N.W. towards Girton, so that the watercourse which we have been following from the east was here deflected northwards after its junction with what perhaps may be considered to have been the main river.

It is of course very difficult to point out the exact place of junction, but from the relations of the Observatory and Castle End gravels to the intermediate chalk ridge we are inclined to think that it was a little farther north, probably in the neighbourhood of How House, where the gravels seem to occupy channels in the Gault, having a general E.S.E. direction.

At Bunkers Hill Farm, opposite the branch road leading to Girton, the well is 8 or 10 feet deep in gravel, and a small excavation behind the houses exposed a few feet of hard compacted yellowish-white gravel, composed mainly of chalk pebbles and small flint stones.

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* *Quart. Journ. Geol. Soc.*, vol. xxii. p. 475.

† Evans' "Stone Implements," p. 485 (1872).

Girton College stands on some thickness of gravel, for a well was sunk 10 feet deep in gravel and sand without reaching Gault, and in old gravel pits near the road, where 3 or 4 feet of brown sandy gravel may be seen.

A little distance north of the College the gravel ridge seems to be worn through down to the Gault, but this latter cannot be exposed over a width of more than 50 or 60 feet, as gravel is again seen in the lane to the northward, and it occupies a considerable area about Girton. Sand and gravel have been dug in several places north of the church (there is 8 feet of it at Mr. Battison's farm), and in a small outlying patch near the rectory 8 or 10 feet of clean white sand was seen banked up against fine yellow gravel.

North of Girton the ground falls again, and Gault is exposed for a little distance, but at the farmstead, about a quarter of a mile from the railway, gravel was again found (about 7 feet deep in the well). Thence a gravel flat extends across the railway to Histon, sloping eastward towards the newer gravels which are here banked up against the older ridge, and ending westwards along a well-marked terrace-like line produced by the action of springs, which are thrown out at its base and drain into the brook that runs to Oakington.

At the cottage by the level crossing over the railroad between Histon and Oakington the well is 13 feet deep, with a bottom of silvery sand, and close by are some large ballast pits now filled with water. From this the ridge trends to the N.W. towards Oakington, and the little brook which flows in that direction from Histon has cut through and re-arranged the older deposits.

There are two outliers on the N. bank of this stream which appear to be remnants of the higher series, and old gravel pits are to be seen in one of these, which caps the high ground N.W. of Histon church.

Continuing the N.W. trend a mass of gravel almost joins that west of Histon, is nearly three miles long, and forms the ridge which for more than a mile is occupied by the village of Long Stanton.

A small pit a quarter of a mile S.E. of Oakington Church showed a foot of brown stratified gravel on fine yellow gravel 2 feet thick, with white sand below.

Another pit just N.E. of the church gave the following succession:—Sandy wash, 2 feet; fine yellow stratified gravel, 4 feet; light-coloured sand, 3 feet.

Another pit a furlong N.E. of the church gave a section of similar stratified beds, as follows:—

	Feet.
Gravelly wash	3
Fine chalky gravel	2
Fine chalky iron-stained gravel	3
Light-coloured sand.	

Professor SEELEY has recorded the fact that he "found shells in the gravel " . . . at Oakington, but in every case they were land or freshwater forms,"* which confirms our conclusion that this line of deposits is of fresh water origin, and a continuation of those traced from the neighbourhood of Balsham and Wilbraham, in which similar shells have been here and there discovered.

The upper part of the ridge by Long Stanton consists of loam, which appears to have been dug in several places for brickmaking, but no good sections are now to be seen; it was, however, exposed in an old excavation N.E. of All Saints Church, and a strong spring is thrown out at the base of the gravel a quarter of a mile N. of Oakington station.

Near the boundary of the gravel, half a mile E. of Long Stanton, is a pit which shows:—

	Feet.
Contorted white marl	0 to ½
Contorted buff loam	½
Fine chalky gravel	2

There are many exposures of this gravel in ponds, and ditches, and in a pit by "the Cottage" at the northern end of the outlier.

* *Quart. Journ. Geol. Soc.*, vol. xxii. p. 475.

On the east side of this large outlier is a small patch of the gravel cut off by the stream. In this is a small pit showing 5 feet of fine, false-bedded chalky gravel and sand.

It must be observed that this old valley gravel here, as elsewhere, occupies comparatively high ground, and has no reference at all to the existing valleys. On the strength of this peculiarity we provisionally include in the same series an elevated patch of gravel on which the village of Over partly stands, but this, except for its continuity with those described, would seem from its position to belong to a higher terrace of the Ouse valley deposits.

The patches between Over and Stanton are similarly included, and one of these, it may be noticed, is still in contact with a patch of Boulder Clay, the lowest of all in the area described. A pit half a mile S. of Over Church shows 4 feet of angular gravel and sand.

It may be that the larger outlier of gravel on which Willingham stands belongs to this series, or, what is more likely, that the small patches on the west, just noted, and which are of a more chalky and loamy description, are the only remaining representatives of these ancient river gravels. Some pits on the east side of road, three-quarters of a mile south of Willingham, show 4 feet of brown rather fine gravel, with patches of sand and loam.

The Chatteris and March gravels being within the borders of the Fen have been described by Mr. Skertchly, but we may record our opinion, based upon their direction, level, and character, that they are an extension of these ancient river deposits, but judging from the shells at the latter place, that they represent their marine termination.

In the neighbourhood of Newmarket there are many other patches of gravel arranged in similar lines, but belonging apparently to a different river system, of which only a small part comes within our area. These patches commence in the valleys that drain the hill slopes by Westley Waterless, Dullingham, Ditton, and Cheveley (in 51 S.E.), and form several series which appear to converge near Exning, whence a gravel-capped ridge extends still farther in a northerly direction.

About two miles west of Dullingham there is a spur of chalk running out from the hills and separating two deep valleys; at the northern end of this, and about half a mile S.S.W. of Dullingham Heath Farm, is a small patch of gravel resting against the flank of the hill; a pit here showed four feet of fine gravel and brown sand with angular flints, some standing on end. Another small patch occupies a similar position on the western side of the spur.

North-west of these, by Bungalore Barn, there is a third outlier, and a much larger spread caps the ridge which stretches thence by Upper Hare Park across the road from Cambridge to Newmarket; this has been excavated in several places for gravel, but no good exposure was seen.

A thick red gravelly soil covers the ground west of New England Farm, and marks the former extension of the deposit; the ridge then trends to the N.E., and there are gravel pits on the high ground between Partridge Hall and the Devil's Ditch; the westernmost of these gave the following section in 1876:—

	Feet.
Brown sandy soil - - - -	1
Hard marly clay with stones - - -	3
Small gravel with large stones at the bottom -	1
Hard clayey sand passing into brown loam -	4

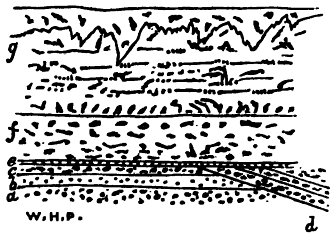
Excavations in other parts of the pit showed hard stony loam with flints and other stones impacted in it, and thin layers of chalky or marly matter, the whole looking like re-arranged Boulder Clay; but at one place softer laminated loam with similar marly layers was seen, about four feet being exposed.

The second pit, 2 furlongs N.W. of the above, showed 8 feet of gravel, composed chiefly of small flints and chalk pebbles with a few larger stones; the lower part was distinctly bedded, but the top was confused and piped with brown sandy loom.

Another outlier of similar material occurs on the next elevation to the N.E., overlooking the village of Exning; a small pit in this showed angular gravel of irregular thickness overlying chalky loam, 4 feet of the latter being visible.

East of Exning a second line of gravels comes in from the S.E., marking the course of an important stream which must have passed over the site of Newmarket; the commencement of this series lies outside our district in the neighbourhood of Cheveley, but we observed some thickness of gravel resting on the flank of the hill about a mile S.E. of Newmarket, and fig. 19 represents the section then seen in the pits marked on the map.

Fig. 19.—*Section in Gravel Pit, half-mile S.E. of Newmarket Railway Station.*



		Feet.
g.	Angular gravel in chalky matrix (the upper 3 or 4 feet brown, and piped into the lower part by dissolution of the Chalk) showing some lines of stratification - -	12
f.	Fine chalky gravel, horizontal - - - - -	4
e.	Yellow sand on the edges of *d* - - - -	¼
d.	False-bedded fine chalky gravel inclined 20° to N.E. (*i.e.* towards the valley) - - - - -	½
c.	Fine chalky gravel. }	
b.	Yellow sand. } - - - - - -	2
a.	Fine gravel. }	

North-west of Newmarket a long ridge commences which is capped with gravel for a distance of more than a mile.

The large pit W. of the Union House gave, perhaps, the best section of thsee gravels in our district; it was as follows in 1876:—

	Feet.
White gravel, consisting mainly of chalk pebbles - -	6–8
Sub-angular flint-gravel, with some chalk pebbles and small patches of sand; greatly contorted and very hard, so compact indeed that it stands like a wall when cut out in square bays the whole depth of the pit, about - - - -	25
Sand, very coarse and gritty at the south end and fine at the north end of the pit - - - - - - -	8

The contorted bedding of the gravel is probably due to the dissolving away of the Chalk beneath.

Gravel pits by the road side half mile N.W. of the Union House showed 6 feet of hard angular flint gravel.

From Exning the ridge turns to the N.E., and the pit one mile N.E. of the church exhibited the following beds:—

	Feet.
Brown sandy soil with flints - - - -	2
Hard chalky sand with flints - - - -	4
Loose chalky gravel and sand - - - -	3 ?
Sharp buff-coloured sand - - - - -	2

Between these two series there are some other patches of gravel which may indicate a tributary stream; they occur on Ling Hill 2½ miles S.W. of Newmarket, and along the ridge which runs southward by Shuckburgh Castle.

The railway cutting west of Dullingham Station exposes a very good section. It shows Chalky Boulder Clay, with some large boulders, resting on the Chalk, and probably at this point occupying a slight hollow therein, as it usually does where the "hard bed" occurs,—here that bed forms a prominent line along the sides of the cuttings. At the west end there is angular gravel with yellow sand resting directly on the Chalk, it has been dug for ballast from a large pit on the north side of the railway. Thus within a short distance are two deposits each resting directly on the Chalk, and it is difficult to determine which of the two is really the uppermost, as the old ballast pit, from slips and overgrowth, is all in confusion.

The gravel is on the same level, and appears to be of the same character as the Post-glacial patches to the west, but on the south side of the cutting (opposite the ballast pit) it is overlaid by what looks very much like Boulder Clay. The clay, however, which is stratified and of slight thickness only, may perhaps be regarded as a wash from Boulder Clay at a higher level, or the gravel seen beneath it at that particular point may be the first setting in of the beds which occur beneath the Boulder Clay in the direction of Bury St. Edmunds.

Just west of Dullingham cutting is a patch of angular flint gravel, with brown and buff sand, small in extent and thickness.

CHAPTER IX.—POST-GLACIAL DRIFT—(*continued*).

GRAVELS OF THE PRESENT RIVER SYSTEM.

These gravels cover a considerable extent of ground in the neighbourhood of Cambridge. There are small patches along the courses of all the main streams at two or three levels, now on one side, now on the other; and where these streams converge near Grantchester the gravels begin to occupy more ground, and in a fairly wide spread continue all the way to the fens.

The time which elapsed between the deposition of the gravels, of which an account has just been given, and those we have now to describe must have been very great. There was time in the interval for an entire change to take place in the drainage system of the country, the old channels were deserted, and the rivers were finally directed into the valleys in which they now flow.

Cam System.—Highest Terrace.

The highest terrace of gravel connected with the present river system has been called the Barnwell series, because of the good sections in it at that place, where it also attains its greatest thickness.

We have seen that in early Post-glacial times a stream issuing from Wardington Bottom flowed to the N.E. towards Triplow and Whittlesford to join the river which then occupied the main valley of the Cam. It appears, however, that this stream gradually changed its course, swinging to the northward, and eventually turning north-westward from Foulmire to Foxton, so that its waters were deflected into the tributary valley of the Rhee. It is probable that at this early period the country lying to the westward was still covered with Chalk and Boulder Clay, and that the present channel of the Rhee above Barrington had no existence, for it is entirely supplied by springs from the Chalk Marl, which could not then have been in their present positions. (See *post*, p. 125.)

The deflection of what we may call the Wardington river was doubtless gradual, and it is difficult to determine the exact age of the gravels which occur at intervals and mark out its newer course. Their patchy mode of occurrence is evidence that they are very old and that the subsequent denudation has been very great; again it is probable that a greater quantity of the gravel was brought down from the Chalk escarpment, and was deposited in early times, for the power of the stream has now so declined that it can no longer carry down such heavy detritus, and there are no recent beds of gravel along its course. It seems likely therefore that the patches of gravel near Foulmire, Foxton, and Harston are the earliest beds belonging to that valley, though we cannot be quite certain of their contemporaneity with the Barnwell gravels.

Near Barrington, on the opposite side of the Rhee Valley, there are two small patches of gravelly silt, which have recently acquired much importance from the remarkable number of mammalian remains obtained from them. These deposits have been described by the REV. O. FISHER, to whose paper we refer for particulars.* We agree with him in thinking that they belong to the same terrace as the gravel near Foxton, but we fail to see in them any proof that the valley of the Rhee west of Barrington had anything like its present extension.

We consider that the main stream at this period came from the south-east as above stated; since, however, its further course in a northerly direction would be barred by the Orwell and Barrington Hills, it was forced to turn to

* *Quart. Journ. Geol. Soc.*, vol. xxxv., p. 670.

the N.E., finding an outlet where the action of springs had caused a gap in the ridge. Such a deflection and obstruction would very probably result in the formation of a large "broad," or lake-like expansion of the river, between Foxton and Barrington. This hypothesis will, it appears to us, account for all the phenomena described by MR. FISHER, and will explain the great difference between the Barrington and Foxton deposits, for all the coarse gravelly material brought down from the southern hills would be deposited at the debouchure of the stream into the southern end of this lake; while in the quiet waters along its northern shore a very different set of beds would be formed, consisting only of the materials derived from the local denudation of the chalk slopes on the west and the clay-capped hills on the north; the product would be a strong silt or marl, and the circumstances would be favourable for the accumulation and preservation of organic remains. The action of springs may have given a westerly extension to this lake.

The shells found at Barrington are the following:—

Helix caperata (common).	Succinea oblonga?
„ nemoralis (rare).	Limnæa palustris.
„ virgata (common).	Pisidium amnicum.

The Mammalian remains are listed on p. 106.

In the valley of the tributary which comes from the S.E. by Linton and Abington there are similar patches of gravel at a corresponding height above the present stream. Some pits north of Pampisford Station showed 10 feet of whitish stratified gravel at the north end of the pit, somewhat contorted, and enclosing patches of loam with shells (*Limnea, Pupa*). Loam is exposed at the angle of the pit, and seems to be banked up against the gravel.

On the hill about a mile N.N.W. of Sawston there is a gravel pit in a small outlier which may once have been connected with the series of gravels we have now to describe.

The first patch of gravel, which can be identified with certainty as forming part of the Barnwell series, occurs just beyond the confluence of the two streams, and caps the high ground to the N.W. of Shelford. The southernmost end of the old channel is cut through by the railway from Cambridge to Hitchin; the middle of the cutting is in Chalk Marl, but at the western end, just before the river bank is reached, the following section is seen:—

	Feet.
Gravelly soil - - - - - -	2
White sandy marl, very hard - - - -	1
Soft white sand with shells - - - -	1
Fine yellowish gravel - - - - -	2

The whole passes eastward into white calcareous sand, and rests against the chalk slope. The following species of Mollusca were found:

Bithinia tentaculata.	Valvata piscinalis.
Helix arbustorum.	———
„ ericetorum.	Cyrena fluminalis.
„ sp.	Pisidium, sp.
Planorbis, sp.	

On the hill northward are some old gravel pits marked on the Ordnance map, but now ploughed over. The gravel-capped ridge which here marks the ancient course of the river forms a strong contrast to the low plain of more recent gravel westward. A second old gravel pit occurs near Vicarage Farm, and further north gravel was seen at several places in the cutting on the Bedford and Cambridge Railway. Between the bridges half a mile south of Trumpington, gravel and sand was seen in the bank, with a bed of hard yellowish-white sandy loam at the base, resting immediately upon clunch. By the 28th milestone (eastward) clunch rises again from under gravel and possibly separates two terraces.

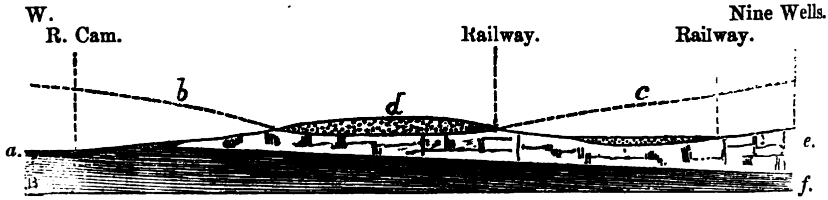
The well at the Green Man, Trumpington, is said to be 23 feet through gravel and sand to clunch. At a coprolite pit half a mile N.N.E. of the church gravel occurred in irregular pockets and trenches 3 or 4 feet deep, being let down into hollows by the solution of the underlying clunch, the intervening tongues of which arched over and sometimes nearly met above the

gravel-filled hollow. In one of these part of a tooth of *Elephas primigenius* was found.

A small gravel pit near Clay Farm on the south-east side shows a few feet of rather coarse gravel and sand.

The river in which the Trumpington gravels were deposited had not therefore cut down to the Gault, but banked its gravels against a chalk slope which was probably continued over the valley in which the Cam now flows; Chalk Marl crops out between the two series of gravels, but the slope of its surface is now westward in an opposite direction to what it must have been when the Trumpington gravels were formed, for at that time it must have sloped eastward. The diagrammatic section (Fig. 20) illustrates this, and indicates the great amount of detrition which has taken place in the interval since the period of the older gravels.

Fig. 20.—Section across the Trumpington Gravels.



Horizontal scale, 2 miles to an inch. Vertical scale, 200 feet to an inch. × × = sea-level. The broken line = the form of the surface when the gravels *d* were deposited.

a. Alluvium; *b*, *c*, *d* = Gravels of the three terraces; *e*, Chalk; *f*, Gault.

Near Trumpington the main stream seems to havs been joined by a tributary coming from the west, which has left its traces in a series of gravels extending from Comberton by Barton and Grantchester.

The patch of gravel upon which the village of Comberton stands rests partly on Boulder Clay and partly on Gault, and its materials were probably brought down by brooks draining off the high Boulder Clay land, like those feeding the present Bourn Brook. Prof. SEELEY has recorded the occurrence of *Rhinoceras tichorinus* in the Comberton gravel. Two small patches of gravel lie to the south-east of this, and serve to show the former continuity of the Comberton and Barton gravels, a small brook which drains off Comberton Field having here made a breach in the old gravel ridge. From a point about three-quarters of a mile west of Barton Church this ridge may be traced continuously through Barton and across the fields to Grantchester, the gravel resting now on Gault, now on Chalk Marl, according to the inequalities in the surface of the latter; its relations to the present surface are shown in Fig. 20, which crosses the ridge about a quarter of a mile W. of Grantchester Church.

There are small gravel pits near the road about the same distance N.W. of the church, and the gravel has been more extensively dug in the paddock between the vicarage and the church; fine flint gravel interbedded with sand was shown here to a depth of about 8 feet in 1875, and we were told that large bones had been occasionally found in it. The ridge of gravel ends abruptly below the churchyard wall, but was doubtless continued originally across the present valley of the Cam to join the Trumpington ridge near Clay Farm.

From Trumpington the river-course appears to have turned north-eastward below Clay Farm, but it is here cut through and breached by the newer series marked *c* in the above diagram. It is found again, however, on the opposite slope by Brooklands Farm and Hinton Cottage. Large gravel pits have been opened between the latter and the railway, and these were from 7 to 10 feet deep in 1876. The soil consists of a dark brown gravelly loam, which is removed over some square yards, leaving an undulating surface of the harder gravel below; the latter consists mainly of flint and chalk pebbles, with a bed of white silty marl near the bottom, underneath which is a layer of coarse gravel resting upon the chalk. The workmen stated that they had found bones and shells in the white marl.

At the railway siding below Brooklands Farm, a similar section was shown, as follows:—

	Feet.
Gravelly soil - - - - -	2
Fine bedded gravel and sand, quite uncompacted and in places stained nearly black - - -	6
Clunch touched below.	

In 1876 the bank opposite the Cambridge Railway Station was cut back for widening the line, and a section of the gravels was thus exposed.

Near the goods sheds this was 16 feet deep, showing first loamy soil, then fine gravel and sand, with thin interbedded layers of greyish white loam and coarser gravel below. These beds thinned out to 8 or 10 feet of sandy gravel near the junction with the Newmarket line, and were seen to rest upon an uneven surface of Chalk Marl, in which many flint pebbles were impacted. Chalk is cut through further along the Newmarket line, but has occasional pockets of loamy gravel.

The excavations made for the foundation of the houses along the road westward from the station were 10 or 12 feet deep in gravel; in those nearer the Hills Road the thickness of gravel was less, and Chalk Marl was found below; the surface of this gradually rose till nothing more than a thin gravelly soil lay above it, and the foundations of the houses at the junction of the roads are in chalk. It is clear, therefore, that between this point and Polecat Farm the gravels still lie in a channel cut in the Chalk Marl as they do near Trumpington.

A quarter of a mile north of the railway station there is a small pit near the chapel in Mill Road from 7 to 10 feet deep in fine gravel and sand, with thin lenticular beds of white marl resting on a dry white clay, which undoubtedly belongs to the lower part of the Chalk Marl; the surface of this sloped eastwards. Some bones in bad preservation, but apparently belonging to an ox (*?Bos primigenius*), were found in one of the sandy layers. Portions of the gravel were compacted into a dark brown iron stained conglomerate.

In foundations for houses east of the cemetery 7 or 8 feet of sandy gravel was observed resting on similar white clay. The same gravel, with loamy or marly layers, underlies the cemetery itself, and extends westward to the corner of Parker's Piece, overlapping on to the Gault, and thinning out, so that the latter comes to the surface. Along the East Road there is generally a good depth of gravel, Gault being reached at varying depths of 10 to 20 feet.

Fuller's gravel pit, about a quarter of a mile N.E. of the Cemetery Chapel, exhibits a good vertical cutting into these gravels; the exposed face is about 10 feet deep, but the workmen stated that the gravel extended to a depth of 14 feet, and that it was underlaid by Chalk Marl, with the coprolite bed about 20 feet from the surface. The upper part of the gravel is much contorted, and long narrow pockets or pipes descend almost vertically downwards, these being filled with dark brown sand and stony loam form a marked contrast to the yellowish-white chalky gravel into which they penetrate. In some of them the bottom is lined with a stiff, brown, stony clay, and the roots of the trees and bushes, which doubtless gave rise to these pockets, are still to be seen.

Northward of this pit gravel is to be seen in several excavations, and the coprolite bed has been worked out under it for some distance.

Much gravel is now obtained from a pit on the southern side of the Barnwell main road nearly opposite the Abbey Church; this exhibited a succession of light coloured sands and fine gravel (often obliquely bedded) with bands of loam and marl similar to that which has been so often noted in the Abbey pits. In 1874 the section here was as follows:—

	Feet.
Loamy soil with roots penetrating into the bed below -	1 to $1\frac{1}{2}$
Dark sand and gravel, contorted and filling hollows in the marl - - - - - - - } Whitish chalky clay or marl - - - - }	4 to 5
Yellow false-bedded sand - - - - -	3 or 4
Sand and gravel, evenly bedded, with thin layers of marl	7 or 8
Clunch, touched at one corner.	

The thickness of the several beds changes as the section is cut backwards, but the top few feet is always more or less contorted, and the coarser gravel lies

near the bottom resting on Chalk Marl, which underlies the pit at a depth of 5 or 16 feet. A tooth of *Rhinoceros tichorhinus* was obtained here together with bones and teeth of *Equus fossilis;* and in 1878 MR. A. F. GRIFFITH obtained a fine flint-hache* from this locality.

In former years the excavations for gravel on the site of Barnwell Abbey afforded excellent sections which have been described by several observers, especially the Rev. P. B. BRODIE in 1844† and Prof. SEELEY in 1866.‡ A flint-flake was found here in 1862 by MR. WHITAKER.§

The general succession as deduced from the descriptions given at different times seems to have been as follows:—

	Feet.
6. Soil and disturbed gravel	3 or 4
5. False-bedded sands	10 to 14
4. Layer of white marly loam	
3. False-bedded sand and fine gravel	
2. Brown marly clay or loam	$\frac{1}{2}$ to 4
1. Coarse pebbly gravel	2 to 4
Total	20 feet.

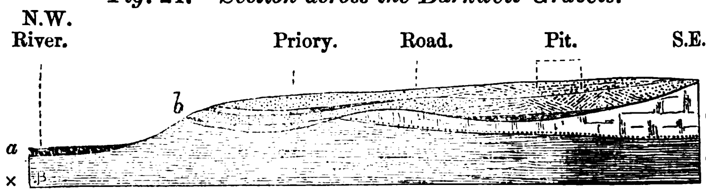
Nos. 3 and 4 were the most fossiliferous layers.

The upper part of the section was still visible in 1875, and was as follows:—

	Feet.
Gravelly soil	2
Sand and gravel, disturbed in places	2
Laminated greyish-white loam, becoming sandy and yellowish below	4
Fine gravel with layers of sand	6

Gault was found below the gravel in this part of the pit, but behind the old Abbey wall the bottom was found of clunch, and the gravel was not more than 7 or 8 feet deep, thickening towards the main road. A section through these pits would therefore be as in Fig. 21.

Fig. 21.—*Section across the Barnwell Gravels.*



Horizontal scale, 50 yards to an inch.

× × Sea Level. *a* Alluvium. *b* Gravels. *c* Chalk Marl. *d* Gault.

The gravels are chiefly composed of flint pebbles, but pebbles of chalk are frequent and phosphate nodules from the base of the Chalk Marl are not uncommon. Larger blocks and boulders were also found occasionally, heaps of which, as they had been thrown aside, were still to be seen in 1875; these consisted of various kinds of rocks, such as granite, gneiss, quartzite, basalt, and porphyritic felstone, with limestone and other sedimentary rocks. All these fragments have doubtless been derived from the Boulder Clay, but they are no proof that any Boulder Clay was then in close neighbourhood to the river; most of them were probably derived immediately from the destruction of the older river gravels through which the Barnwell stream must here have cut its way, and before they found their way into these beds they may have formed part of still older gravels like those capping the Gog-Magog Hills.

* *Geol. Mag.*, Dec. II., vol. v. p. 400.

† *Cambridge Phil. Trans.*, vol. viii. pt. 1. p. 138.

‡ *Quart. Journ. Geol. Soc.*, vol. xxii. p. 475.

§ Evans' Ancient Stone Implements, p. 485, *London*, 1872.

The Barnwell gravels were in their turn cut through by the river when it flowed through Chesterton, and formed the gravels which stream away to the northward by Milton and Waterbeach; but when the beds of gravel, sand, and marl were being deposited under the site of the Abbey grounds the eastern bank of the river curved round in all probability across the present course of the Cam, and was continuous with the island of Chalk and Gault on which the windmill N.W. of Chesterton stands.

Between this island and the similar outlier north of the Castle Hill is a trough nearly half a mile wide and filled with gravel and loam, in which there were once many pits, but none are now open. Some years ago, however, there were gravel pits near the eastern end of Victoria Road, and their section was observed by the Rev. O. Fisher, from whose paper the following is taken:—*

Warp.
White sandy brickearth.
Yellowish sandy earth.
Fine sandy gravel.
Yellowish brickearth.
Fine gravel, more contorted than the layers above and below.
Sand.

It will be seen that these beds form a succession very similar to that in the Barnwell pits; the sands contained *Bithinia* and other small shells, but no specimens of *Cyrena fluminalis* were found. Mr. Fisher comments upon the curiously eroded line of junction between the "warp" and the subsoil in this and other instances. He considers it to be the intersection of subterranean channels of drainage, along which he believes there is a slight forward movement of the particles of the soil or warp. "This," he says, "may account for the flat-topped elevations, like the tenons in the framework of a dissected puzzle, which often occurs near the line of junction of the warp with the subsoil, especially (if I mistake not) where the latter contains calcareous matter and has suffered partial solution. The erosion at the bottom of two contiguous subterranean channels would leave an elevated ridge between them, and the superincumbent soil sinking in a general mass would then flatten the crest of the ridge." We quite agree with this explanation, and have observed similar instances in many of the coprolite pits near Cambridge, where the clunch is covered with a gravelly soil, particularly at Trumpington, (see *ante*, p. 95) where Professor Seeley also noticed "the great extent to which the upper 2 or 3 feet (of the gravel) are contorted and folded.*

Northward from the trough or channel above mentioned the gravels spread out over a larger area towards Impington and Histon. In the ditch which runs through the fields toward the old camp at Arbury fine yellow gravel is seen at the southern end, and reddish-brown laminated loam where it passes under the road east of Arbury; and its continuation eastward is dug through a considerable thickness of gravel and sand, compacted in places by a ferruginous cement as to form a hard conglomerate, lumps of which are scattered over the fields. Where the ditch runs by the new roadway about a mile east of Arbury a black peaty loam was exposed in the bottom of the ditch underlying about 5 feet of gravel and sand.

At the farm on the road west of Arbury the well was dug through 9 feet of gravel into a quicksand with water, and a similar supply of water was obtained at the windmill south of Histon Station.

The same gravel and sand, occasionally compacted by ferruginous matter, is to be seen along the ditch or watercourse which runs through the fields north of Hogs Hall, and passing under the railway traverses the village of Histon, then turns to the N.W. and cuts through the older gravels between Histon and Oakington; this brook has, of course, re-arranged portions of both series.

That which we have called, for convenience sake, the Barnwell series has suffered much denudation in the neighbourhood of Histon and Impington, and it is impossible to unravel the history of all the patches of gravel, sand,

* *Quart. Journ. Geol. Soc.*, vol. xxii. p. 551.
† *Quart. Journ. Geol. Soc.*, vol. xxii. p. 475.

and loam which occur in this district. The gravel capping the rising ground in Impington Park may belong to some older formation, but it seems to be connected with the loamy deposit on which the church is built, and this appears to run down to lower levels; north of the church are some excavations in a soft yellow sandy loam, very clean and somewhat laminated, which is seen again in the brickyard to the eastward, where it is rather more stony. In another part of this brickyard pockets of loamy gravel containing large boulders descend into the Gault, the stones and rocks being such as would have been washed out of neighbouring Boulder Clay; similar yellow loam is to be seen in ditches about half a mile south-eastward.

East of Impington these gravels have been almost entirely swept off the surface of the country, the only traces of their previous extension being found in two long and narrow channels filled with sand and gravel, which are prolongations from the main mass near Kings Hedges; they are intersected by the numerous ditches which here separate the fields, and by means of the evidence thus afforded the gravel-filled channels were traced over the ground. Their terminations point across a shallow valley north of Impington (formed by a more recent line of drainage) towards an outlying gravel-covered plain which stretches north and north-east of Histon.

At the fork of the roads, nearly half a mile N.E. of Histon Church, there is a thickness of from 6 to 10 feet of gravel above the Gault, and further in the same direction gravel has been extracted from several places in the fields; it is everywhere composed of small pebbles of flint and chalk, and much sand appears to be mixed with it. This gravel plateau is cut off quite suddenly along a line running nearly due east and west, so that there is a straight terrace-like descent, nearly a mile long, on to the lower plain formed by the Gault towards Cottenham.

No patches of gravel have been found north of this line, and it does not seem probable that the series we have been tracing was ever continued across the ridge of high ground (formed by the outcrop of the Lower Greensand and Kimeridge Clay) which runs north-eastward from Oakington to Cottenham. This ridge, at the time we are treating of, was doubtless even higher than it is now, and we know that from Oakington southwards there was also high ground capped by the more ancient river gravels.

Thus the outspread of gravel about Arbury, Impington, and Histon seems to have been accumulated in a kind of lake or wide reach of the river, in which there may have been Gault islands, separated by the deeper channels made by the stream as it changed its course from time to time. From this lake or "broad" there could be no outlet except in one direction, N.E. by Landbeach; we are therefore led to inquire whether there are any indications of the former continuation of the gravels in that direction.

Now N.W. of Milton there occurs a long outlying patch of gravel, separated from the newer series by a Gault slope, and traversed along its whole length by the old Roman road; gravel to a depth of at least 4 or 5 feet is shown in the ditches on either side of this road, and the elongated extension of the outlier points northward to another small patch in the fields a little more than half a mile N.W. of Landbeach Church.

These indications, therefore, seem to confirm the surmise that the Barnwell gravels were once continued in a north-easterly direction from Histon; but a newer series, that, namely, which extends from Chesterton through Milton, here intervenes, and again cuts through what appears to have been the course of the older gravels, consequently all traces of their occurrence in this district are destroyed or obscured. It is interesting, however, to find that by the farm called Denny Abbey certain patches of gravel seem to separate themselves from the newer deposits, keeping at a somewhat higher level, and it is quite possible (not to say probable) that these belong to the older Barnwell series; we have, therefore, ventured to indicate this on the map (Pl. 4) as the course of the river during this period.

Denny Abbey stands on the first of these patches, which forms a gravel-capped ridge, elongated towards the N.E., and nearly surrounded by slopes of Gault, except on the western side, where newer loams have been banked up against it. By Causeway End Farm gravel again occurs, and the house called High Elm, still further N.E., stands on another small outlier which forms a kind of island surrounded on three sides by the fen.

Beyond this point the continuation of the series has either been entirely swept away, or is to be sought for below the fen deposits towards Streatham and Ely.

Cam System.—Intermediate Terrace.

In the tributary valleys of the Cam many patches of gravel appear to occupy intermediate levels between those beds we have described and the more recent deposits bordering the course of the present streams; such are found near Abington and Babraham, and in the main valley near Chesterford, Duxford, and Whittlesford. It is impossible, however, to separate these from the gravels of earlier or later date, for the river, in shifting its channel, has continually removed and re-arranged previously deposited beds, so that in many places a continuous slope of gravel has been formed without any separation being visible between the different stages or terraces.

With regard to the age of the gravels in the valley of the Rhee, we have already pointed out that the materials were brought down by the stream issuing from Wardington Bottom, and have indicated the difficulty of correlating the deposits with those in the main valley near Cambridge.

Similar difficulties stand in the way of discussing the relative ages of the gravels in the valley of the Bourn; some of the patches are at a higher level than the others, but probably no two are exactly at the same relative level or of precisely the same age.

It happens, however, that between Shelford and Cambridge a continuous deposit of gravel has been preserved, occupying an old channel, which was evidently the course of the river at a period later than that of the Barnwell gravels and before the time when the present channel below Shelford was formed.

If the general direction of the Cam valley be prolonged from Whittlesford through Great Shelford, the line would pass along the low ground which stretches northwards between the Chalk Hills on the one hand and the low ridge formed by the Trumpington gravels on the other; it is this strip of low ground which is occupied by the gravels in question (see Fig. 20, p. 96).

Shelford and Stapleford stand at the entrance to this channel, and gravel is or has been shown in many excavations about these villages, but so many different river courses seem to have converged towards this locality that a complete disentanglement of the several gravel terraces is well-nigh impossible. The following exposures were noted in 1875.

In a saw pit about a quarter of a mile S. of Stapleford Church 6 feet of gravel and interbedded chalky sand were seen; the well in cottage garden near by was stated by the well-sinker to be through 8 feet of sand into white clay or clunch (12 feet).

A pit in the field between the river and the main road near the old turnpike showed about 8 feet of coarse gravel, indistinctly bedded, with occasional patches of fine sand.

At Great Shelford there is said to be from 8 to 10 feet of gravel in the churchyard; the gravel pit about 100 yards N.W. of the church exposed 6 or 7 feet of gravel and sand.

The railway cutting south of the station showed pockets of sandy gravel and loam overlying the clunch, passing into a bed of gravel 8 feet deep, which was at one time worked in the yard of the Station Inn.

From a field opposite the Greyhound Inn, half a mile N. of the church, much gravel has been obtained, and also from the railway cutting close by,

where 8 feet of sandy gravel is seen overlying white clay (? Chalk Marl); *Succinea*, *Helix sp.*, and *Achatina acicula* were found here.

The average depth of the gravel at the northern end of Shelford is 10 feet. Along the ditch or watercourse running thence N.N.W. gravel is seen in many places, overlaid in some of the side-ditches by a whitish clay containing shells; *Helix hortensis*, *H. rufescens?*, *Bithinia tentaculata*, *Succinea putris*, *Planorbis marginatus*, and *Pisidium amnicum* were collected from this clay, which is doubtless much more recent than the underlying gravel.

The water issuing from the "Nine Wells" near "Steeple Hill" runs westward to join this watercourse, and the stream below their union is known as "Vicars Brook." The gravel continues to border both sides of this, with an average breadth of half a mile, and opens out into the great spread of gravel upon which most of Cambridge is built. A pit close to the brook, a quarter of a mile S. of the point where it crosses the Trumpington Road, showed the following section:—

Fine flint gravel and sand, with strong springs issuing from the base, 6 feet.
Bluish-grey clunch, with dark glauconitic marl at the bottom, 9 feet.

The plot of ground called Coe Fen, opposite the Botanical Gardens, has been worked over for gravel, and the gardens themselves stand upon 7 or 8 feet of the same material, the bottom of the pond being in the Gault; the Chalk Marl and coprolite bed probably crop out under the gravel near the hothouses, for a well outside the N.E. corner of the gardens pierced about 8 feet of soil and gravel, with 6 feet of clunch below, and another at the eastern end of Norwich Street was dug through gravel (6 feet), "white clay" (7 feet), "coprolites" and Gault (1 foot).

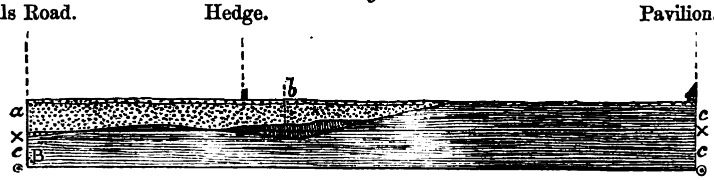
At the house called the Leys excavations for new buildings showed only 4 feet of gravel and sand over Gault. A deep trench, opened for drain work, along Trumpington Road from the corner of Downing Terrace exhibited this section at the N. end:—

Bedded gravel and sand, 8 feet.
Loose quicksand, with water, 2 feet.
Gault clay, 6 feet.

The surface of the clay, however, rose rapidly southwards, little or no gravel being found above it at a distance of 20 yards in that direction.

A similar trench leading from the pavilion in Fenner's Ground to the Hills Road gave the interesting section shown in Fig. 22, the gravel here being backed up against the Gault.

Fig. 22.—Section along Drain from Fenner's Ground to Hills Road, Cambridge.



\+ Bottom of drain. (•) Level of Cam.
a. Gravel. *b.* Chalk Marl. *c.* Gault.

This ridge of Gault extends northwards across Parker's Piece, by the eastern side of Christ's Piece and New Square, to Maids Causeway and Butts Green, thus separating the Barnwell Terrace from the newer gravels underlying the rest of Cambridge; it is not unlikely that the gravel at the northern end of the town from Corpus College to Midsummer Common may be more recent than that found to the southward by Downing College and the Botanical Gardens, for the level of the latter district, south of Downing Street, averages 11 feet higher than that of the former. The following is a list of places in the town between the river and the ridge of Gault above-mentioned, where recent excavations have shown a greater or less depth of gravel.

Downing College (new buildings, 1875), 8 feet of gravel and sand over Gault.
Pembroke College (new buildings, 1875), 7 feet of gravel, Gault seen below.

Opposite Police station, about 8 or 10 feet of gravel.

St. Andrew's Street, foundations of house near Mr. Sayles, 8 feet of sandy gravel over Gault.

New Corn Exchange, 10 feet of gravel above Gault.

Caius College (new buildings), 10 feet of gravel with much water at the bottom.

St. John's Chapel, 4 feet of gravel with Gault below.

Corner of Jesus Lane, 15 feet of gravel said to have been found in digging a well, with yellow loam below, resting on Gault.

A well-marked terrace of gravel occurs on the west side of the river, and extends from Croft Town through Newnham to Trinity College Gardens; the level of this terrace is probably much the same as that by New Town and Downing College, or about 40 feet above Ordnance datum.* The average depth of the gravel as seen at several places in Croft Town, at Newnham Hall, and in Parallelogram Road, is about 9 or 10 feet.

At Chesterton similar gravel occurs at about the same level, and has been extensively worked in the fields bordering the northern side of the river south-west of the church.

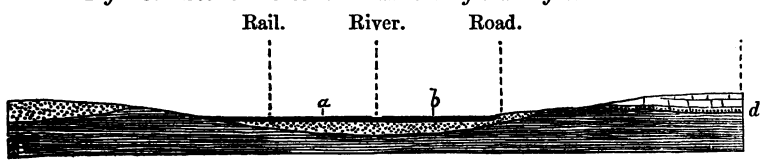
The pits open in 1875, 76 exposed 12 feet of gravel with occasional seams of fine sand, and water coming in at the bottom prevented deeper excavations. The gravel is mainly composed of flints, but quartzite pebbles, fragments of Oolitic limestones, and of various igneous rocks not unfrequently occur. Many bones have been found in these Chesterton gravels, and some are preserved in the Woodwardian and Anatomical Museums. The thickness of the gravel appears to lessen towards the N.W., the following section being visible (1875) in a small pit near Captain Wragg's house on the Chesterton road:—

	Feet
Dark-brown gravelly soil - - - -	3
Yellowish fine flint gravel - - - -	4
Light blue Gault, quite dry, shown below.	

Northward from Chesterton this gravel forms a well-marked terrace parallel to the river Cam for some distance, and about three-quarters of a mile wide. Gravel, sand, and loam are shown in many of the deep ditches between Chesterton and Milton, the stream which had brought the gravelly detritus thus far down its channel having apparently sorted and sifted out the coarser and finer materials into separate beds.

North of Milton this series of beds widens out somewhat, and slightly changes its direction, passing due north between Landbeach and Waterbeach, so that a strip of Gault appears between its eastern edge and the alluvium of the Cam; a section across the Cam Valley, where this commences about five furlongs S.S.W. of Waterbeach Church, would appear as in Fig. 23.

Fig. 23.—Section across the Cam Valley south of Waterbeach.



Vertical scale, 100 feet to an inch. Horizontal, 5 inches to a mile.
a. Alluvium. *b.* Recent gravel. *c.* Higher gravel terrace. *d.* Chalk marl. *e.* Gault.

A gravel pit half a mile west of the church has been dug to a depth of 7 or 8 feet, and there are several old pits on Landbeach Common whence gravel has been obtained.

North of this the width of the terrace is about a mile and a quarter, and its eastern boundary forms a ridge by Windfold Farm, separating fields in which the character of the soil is entirely different, light sandy ground being found on the western side, while the soil on the eastern slope toward Waterbeach Joist Fen is the stiff heavy staple formed by the Gault.

* Roughly speaking, the levels of the three terraces are as follows:—Lowest terrace, 30 feet; Middle terrace, 40 feet; Barnwell terrace, 50 feet.

Gravel and sand may be seen in many places along the road to Ely, part of which is carried along the ancient Roman Way. Gravel pits, half a mile N.W. of Goose Farm, exhibit about 6 feet of sandy gravel; the stones are mostly flints, but rock fragments and phosphate nodules from the Lower Greensand are plentiful (the outcrop of this formation being just southward), a few chalk pebbles occur, but these have travelled far and are very small.

This gravel is traceable northward by Long Drove till it passes under Chaff Fen, it appears, however, to have suffered great denudation in this district, the small gravel-pits near the fen showing only 4 or 5 feet of gravelly sand.

One just north of the house at the end of Long Drove showed the following beds:—

	Feet.
Black peaty soil (edge of fen) - -	$1\frac{1}{2}$
Soft grey silt - - - -	1
Fine gravel and sand - - -	3
Fine silt full of water, with Kimeridge Clay below - - - -	$1\frac{1}{2}$
	7

Another about a quarter of a mile to the S.W. showed:—

	Feet.
Black peaty soil - - - -	1
Soft silt and sand - - - -	$1\frac{1}{2}$
Fine gravel and sand, interbedded (water at bottom) - - - -	3

Eastward by Denny Abbey it is more loamy, and has better resisted denudation; hard gravelly loam, with patches of white loamy clay, appears in the bank of the ditch north of the Abbey, crushed shells occur in this, *Succinea* and *Planorbis* being distinguishable. North of this Gault and Lower Greensand come to the surface.

Cam System.—Lowest Terrace.

We have already spoken of the gravels forming the lowest level or terrace at only a slight elevation above the alluvium which borders the present streams. In the main valley of the Cam an almost continuous series of such gravel is found below Chesterford and Duxford, as far as Shelford, but it presents few features worthy of note. The extensive pits just east of Whittlesford Station illustrate the position of these beds; the workings are very shallow, not more than 4 or 5 feet deep, and the gravel is made up of small pebbles of chalk and flint; there is a bed of greyish loam at the top, and bones have been occasionally found near the bottom.

Gravels occupying a similar relative position occur in the valley of the brook coming down from Linton and Bartlow*; at Hildersham, for instance, just north of the Hall, there is 10 feet of whitish stratified gravel, with patches of sand and loam containing shells. From Abington to Stapleford the south side of the stream is bordered by a continuous tract of gravel, parts of which belong to this lowermost terrace.

We have also pointed out that the present course of the Cam below Shelford is quite different from that which it pursued in older times, when the river passed in a northerly direction through Shelford, and did not join the combined waters of the Rhee and Bourn till it reached the neighbourhood of Cambridge. The channel which it has since cut for itself by Little Shelford and Hauxton is comparatively modern, and the gravel flats on either bank are more recent than the gravels of Great Shelford, and form

* For notes of pits at these places, see Memoir on Sheet 47, p. 72.

a continuation of the series above mentioned as stretching northward from Whittlesford.

It would appear, indeed, that in consequence of this change in the channel a considerable lake was formed in the neighbourhood of Hauxton; before the outlet by Hauxton Mill was deepened sufficiently to allow of the free outflow of the stream, the barrier of Chalk Marl through which it here passes would pond back the waters and produce a lake over the low ground to the eastward, in which the gravel brought down from above would naturally be deposited. The outspread of gravel by Hauxton is at any rate suggestive of this having been the case.

In 1872 some 6 feet of contorted gravel over Chalk were seen in a pit a quarter of a mile west of the church and in 1875 the coprolite pits near Hauxton Mill showed the following section, but the beds change and thin out eastward towards the road:—

		Feet.
River Gravel	Coarse gravel with dark brown stains	5
	Fine yellowish sand	1
	Fine gravel	1
	Evenly-bedded sand and silt	2½
	Fine gravel	½
Chalk Marl	Grey clunch, rather rubbly	8
	Dark Greensand, with coprolites	1

The tongue of land in the angle between the Cam and Rhee above their junction is also covered with gravel, but no exposures were seen in it.

The Bourn Brook which next joins the river is skirted by a similar series of gravels, in a continuous strip from Bourn to near Eversden; another narrow band commencing at Fox's Bridge, south of Comberton, where several small pits are open, and continuing by Lord's Bridge, between the railway and the brook, till the latter falls into the main stream.

The tract of gravel which borders the alluvium on the eastern side of the Cam opposite Grantchester is at a rather higher level, and probably belongs to an intermediate terrace formed by the combined streams of the Rhee and Bourn, when the main stream of the Cam was flowing on the other side of the Trumpington ridge.

We have already spoken of the gravel underlying the older part of Cambridge as being at a slightly lower level than that to the south against which it is banked. The terraces are, however, much more distinct on the western side of the river north of Newnham; the road along the "Backs" of the colleges by Clare Piece, Trinity Paddock, and St. John's Garden being on the lower terrace, and a marked rise being traceable from this to the higher terrace, through the gardens belonging to King's, Clare, and Trinity Colleges.

A similar rise or bank appears to separate the intermediate terrace north of Chesterton from the lower gravel flat forming Chesterton Common, and extending nearly as far as Milton. This gravel has been worked in the field close to Chesterton Junction, the pits open in 1875 showing 10 feet of fine yellowish gravel over a black sandy loam or silt, full of water. The workmen stated that these beds thinned out rapidly to the N.W., the underlying Gault rising to within 2 feet of the surface about 100 yards off in that direction. A fine elephant's tusk, now in the Museum of Comparative Anatomy, was recently found here.

Similar gravel is worked a little distance northward by the side of the Cambridge and Ely line. Beyond this again, and bordering the northern end of Milton Fen, is a narrow strip of gravel, banked as before against the higher terrace, and sloping eastward under the peaty alluvium, the thin end of which is shown in Fig. 23, p. 103.

On the opposite side of the river there is a small patch by Biggin Abbey, probably at a somewhat higher level, and near Horningsey is a tract of gravel, apparently indicating the former incoming of a small tributary from the south.

Gravel has been worked at several places under a thin alluvial covering by the side of the railway beyond Waterbeach, and it probably underlies most of Waterbeach Joist Fen, which spreads out between Denny Abbey and Upware.

Cam System.—Fauna of the Gravels.

In the preceding pages an attempt has been made to separate the terraces of gravel in the Cam Valley, and to give some account of the changes which have taken place, and of the deposits which have been successively formed, during the excavation of this valley and its tributaries.

The following list contains the names of the fossils known to occur in each of the series described, but it is necessarily only a first attempt. The most ancient series of river gravels has hardly yet been explored, and the first column contains only the names of those few species found by ourselves, and of the animals represented in the collection of bones from the Lark's Hall gravels, lately presented to the Woodwardian Museum by Mr. Prince, of Balsham.

The second column (of the Barnwell Gravel) is more complete; a good collection exists in the Woodwardian Museum, and, besides the lists previously made by Mr. Brodie and Mr. Dewick, we are now able to give some additional species on the authority of Mr. Alfred Bell. The Mammalia and Mollusca lately found at Barrington are also included.

The material for filling in the succeeding columns is very scanty, large numbers of bones have been found from time to time in the gravels near Cambridge, and many are preserved in the Woodwardian and Anatomical Museums, but a record of the exact localities where they were found has not always been preserved, so that they are useless for the purpose of the present list.

List of Fossils from the Gravels of Cambridgeshire.

——	Ancient Series.	Barnwell Series.	Middle Terraces.	Lowest Terrace.	Warp and Alluvium.
VERTEBRATA.					
Bison priscus, *Bojan.*	...	×			
Bos longifrons, *Owen.*	...	?	...	×	×
„ primigenius, *Bojan.*	×	×			
Cervus megaceros, *Hart.*	×	×			
„ elaphus, *Linn.*	...	×			
Elephas antiquus, *Falc.*	×	×			
„ primigenius, *Blum.*	...	×	×	×	
Equus caballus fossilis, *H. V. Meyer*	×	×	×	...	×
Felis spelæa, *Goldf.*	...	×			
Hippopotamus major, *Desm.*	×	×	×		
Hyæna spelæa, *Goldf.*	...	×			
Meles taxus, *Linn.*	...	×			
Rhinoceros tichorhinus, *Cuvier*	×	×			
Sus scrofa, *Linn.*	...	?	...	...	×
Ursus spelæus, *Blumb.*	...	×			
Anser	...	×			
INVERTEBRATA (MOLLUSCA). *Gasteropoda.*					
Achatina acicula, *Müll.*	...	...	×		
Ancylus fluviatilis, *Mull.*	...	×			
„ lacustris, *Linn.*	...	×			
Bithinia tentaculata, *Linn.*	...	×	...	×	
Bulimus Lackhamensis, *Mont.*	...	×			
„ (Azeca) tridens, *Pult.*	...	×			
„ (Zua) lubrica, *Müll.*	..	×			
Carychium minimum, *Müll.*	...	×			
Clausilia biplicata, *Mont.*	...	×	...	...	×
„ rugosa, *Drap.*	...	×			
Cyclostoma elegans, *Müll.*	...	...	...	...	×
Helix arbustorum, *Linn.*	...	×			

List of Fossils, &c.—*continued.*

	Ancient Series.	Barnwell Series.	Middle Terraces.	Lowest Terrace.	Warp and Alluvium.
INVERTEBRATA (MOLLUSCA)—*Gasteropoda*—*cont.*					
Helix caperata, *Mont.*	...	×			
„ concinna, *Jeff.*	...	×			
„ ericetorum, *Müll.*	...	×			
„ fruticum, *Müll.*	...	×			
„ hispida, *Linn.*	×	×			
„ lapicida, *Linn.*	...	...	...	...	×
„ nemoralis, *Linn.*	...	×			
„ pulchella, *Müll.*	...	×			
„ pygmæa, *Drap.*	...	×			
„ rotundata, *Müll.*	...	×	...	...	×
„ rufescens, *Penn.*	...	×	× ?		
„ virgata, *Da Costa*	...	×			
Hydrobia marginata, *Mich.*	...	×			
Limnæa auricularia, *Linn.*	...	×			
„ palustris, *Müll.*	...	×	...	...	×
„ peregra, *Müll.*	...	×			
„ truncatula, *Müll.*	...	×			
Paludina contecta, *Millet*	...	...	...	...	×
Planorbis carinatus, *Müll.*	...	×			
„ complanatus, *Linn.*	...	×	× ?	...	×
„ corneus, *Linn.*	...	×			
„ glaber, *Jeff.*	...	×			
„ nitidus, *Müll.*	...	×			
„ spirorbis, *Müll.*	...	×			
„ vortex, *Linn.*	...	×	...	...	×
Pupa marginata, *Drap.*	× ?	×	...	× ?	
„ umbilicata, *Drap.*	...	×			
Succinea elegans, *Risso*	...	×			
„ putris, var. major	...	×	×	×	
„ „ „ minor	×	×			
„ oblonga? *Drap.*	...	×			
Valvata cristata, *Müll.*	...	×			
„ piscinalis, *Müll.*	...	×			
„ „ var. antiqua, *Morr.*	...	×			
Vertigo antivertigo, *Drap.*	...	×			
„ moulinsiana, *Dupuy*	...	×			
„ pygmæa, *Drap.*	...	×			
Zonites cellarius, *Müll.*	...	×			
„ fulvus, *Müll.*	...	×			
„ nitidus, *Müll.*	...	×			
„ nitidulus, *Drap.*	...	×			
„ radiatulus, *Alder*	...	×			
Lamellibranchiata.					
Sphærium (Cyclas) lacustre, *Mull.*	...	×			
„ cornea, *Linn.*	...	×			
Cyrena fluminalis, *Müll.*	...	×			
Pisidium amnicum, *Müll.*	× ?	×			
„ fontinale *Drap.*	...	×			
„ nitidum, *Jenyns*	...	×			
„ pulchellum, *Jenyns*	...	×			
Unio limosus	...	×			
„ littoralis, *Lam.*	...	×			
„ pictorum, *Linn.*	...	×			
„ tumidus, *Retz.*	...	× ?	...	...	×

Gravels connected with the Wilbraham River and Fulbourn Waters.

In the times of the ancient river-system which has left such interesting memorials of its existence in the long ridges of gravel described in a previous chapter, the springs which now rise near Wilbraham, Fulbourn, and Teversham were doubtless nearer together and poured their waters into the river which then flowed westward from Quy-cum-Stow. As, however, the declivities bounding that ancient valley (see fig. 18) were gradually cut backward by the action of rain and of the springs themselves, the sources of the latter would travel backward also and become more separated from one another.

Eventually after the old channels had ceased to carry off the main drainage of the country, there would come a time when the streams from the springs would be directed into the central ground now occupied by Wilbraham Fen, and being ponded back by the line of the old river-course would form a lake or marsh whose level would be determined by the height at which the waters could escape over the lip of the basin by Quy-water Bridges. The stream issuing from this would then flow northward to join the Cam.

There are four principal sources which contributed their supply to the formation of this lake; the first rises just to the eastward of Great Wilbraham Church, and the stream flowing west from this is called the Wilbraham Water, the second is that called Shardelows Well, east of Fulbourn; the springs which rise along the southern edge of Fulbourn Common and run into Caudle Ditch form the third source, and the springs supplying Teversham Ditch the fourth.

Traces of gravels still remain which must have been deposited when these streams ran at a higher level and possibly before the above-mentioned lake was formed; thus a patch of gravelly soil occurs at Little Wilbraham considerably below the level of the more ancient series and above the sandy and gravelly soil which appears to mark out roughly the site of the subsequently formed lake. Another patch of similar material, and occupying a similar position, is found to the north of Fulbourn, and is shown in the railway cutting at its southern edge, where a few feet of loamy gravel are to be seen, pipes and strings of which descend into the rubbly Chalk Marl below.

Further north the rising ground between Candle Ditch and Teversham Fen is capped with loamy soil, and prolonging the direction of these two patches we come to another outlier commencing in the fields six furlongs N.W. of Quy Mill. The ditches north of this point cut into beds of loam, sand, and chalky gravel, and the length of the patch is about three-quarters of a mile. North of this the fields still present a gravelly soil, and the series was probably once continuous with the gravel previously mentioned as occurring to the N.E. of Horningsey, and extending to the border of the present alluvium of the Cam.

The thin covering of gravel and sand which spreads over the low grounds east of Fulbourn and passes under Wilbraham Fen was probably deposited at a somewhat later date than the series above described, and appears to have formed the floor of the lake which once covered this area. Shallow pits have been dug at several points in this deposit, near Hawk Mill, for instance, and also by the cottage on the droveway half a mile N.W. of Frog End. The well here was said to have been dug through the following beds:—

	Feet.
Black soil	2
Fine gravel	2
Yellow sandy loam	6
Clunch	1

Finally, as the outlet by Quy-water Bridges was deepened by the outflow of the water, the level of the shallow lake would become less and less till it was converted into a mere marsh or fen; and it was probably in this condition at the time when the Fleam Dyke was constructed. The people who threw up this defence carried it from Balsham to Shardelows Well, where the marsh began, thence to Quy Bridge there was probably an impenetrable morass which formed a natural defence, and the line by which the Dyke is continued on the Ordnance map has no real existence on the ground; it was only necessary to defend the country from Quy Bridge to the Cam at Fen Ditton, and High Ditch Lane is the true continuation of the Fleam Dyke.

The Fen has been drained and a large part of it brought under cultivation, but there is still 12 or 14 feet of peat at the N.W. end. Men are still living who can remember this in the state of a marshy pool, on which punts were employed in shooting wild fowl; this was drained in 1804 and the water taken under the embankment of the Wilbraham river by means of a hollow trunk; this having become useless a brick tunnel was made in 1863, and the drainage level at that time was found to be 6 feet below that marked by the old trunk; the level of the fen had sunk, therefore, 6 feet in about 60 years.

The bottoms of the (usually dry) valleys which drain off the higher slopes of the Chalk hills are often occupied by gravelly soil or rainwash to a depth of some feet; thus in the valley running northward from Balsham there is a deposit of dirty gravel and sand extending from Wadley Hall in a narrow strip beyond Larks Hall, which has probably been formed to a great extent from the waste of older river gravels once existing at higher levels.

Similar deposits occur in Westley Bottom to the north, and there assume the character and importance of actual river-gravel; they flank the N.E. side of the older gravel-ridge for some distance, but die out beyond Bottisham Heath Farm. Small pits have been opened at several spots, and show 4 or 5 feet of soft sand or sandy gravel. Their origin is doubtless to be found in the detrition of the older gravels by rain and floods.

Valley of the Ouse, Higher Terrace.

The valley gravels of that small portion of the Ouse which traverses our area occur in two terraces, the same as those described in the several channels of the Cam system. The older occupy plateaux a few feet only above the level of the alluvium, but are cut off from it and from the more recent deposits of gravel at a lower level by a narrow outcrop of Oxford Clay. There is but one exception, and this may be more apparent than real; a large patch N. of Somersham, which is evidently part of the higher terrace, at and near that village, but seems to pass without a break down to the fen, and is so mapped as no clay occurs between; either the two terraces are close together at the northern end and a sandy wash between obscures the division, or there is but one

terrace (the higher) and a wash from this runs down the gentle slope to the fen, and entirely obliterates the real boundary.

On the right bank of the river there is but one spread of this gravel (unless that at Over should prove not to belong to the ancient river series); it is, however, of good size, two miles long and nearly a mile broad, extending from Fenny Stanton to Fenny Drayton. The gravel has been dug in several places, but the only good section is in the pit half a mile S.E. of Fenny Stanton, which is 5 feet deep in fine very chalky gravel, with patches of false-bedded light-coloured sand and loam, the beds contorted.

On the opposite bank of the river a similar outlier of gravel occurs capping the higher ground, forming an excellent site for the villages of Holywell and Needingworth. Its southern end comes close to the marsh, but the bank is steep, so that the base of the gravel is at least 10 feet above the surface of the alluvium. There are many pits in this gravel, especially at Needingworth; at one, just W. of Holywell Church, there is a depth of 7 feet of fine subangular gravel, with thin bands of sand, and a line stained by oxide of manganese, and similar gravel occurs with brown sand in the pits on the eastern side of the church. At a pit near the cross roads in the village of Needingworth there is fine subangular gravel, mostly of flint with some quartzites, to a depth of 9 or 10 feet, with sand and water at the bottom. Gravel of the same description is seen in a pit just E. of the village.

The villages of Colne and Bluntisham stand partly on the next patch of gravel at this level; it is of the same description, but is exposed in few sections; a small pit in the farmyard, E. of Colne Church showed several feet of good gravel.

A smaller patch is that on which Colne Windmill is situated; a small pit in this, just S. of the Somersham Railway Station shows 2½ feet of brown angular gravel.

Another large spread of gravel, 2 miles long and a mile broad, comes on northward from Somersham Station, and is traversed along its whole length by the St. Ives and March Railway. The gravel is exposed in the cuttings, but is best seen in the many pits in and around the village of Somersham. It is interesting from having yielded a fine skull of *Bos primigenius*, with horns attached, which has been placed in the Geological Museum at Jermyn Street through the kindness of Mr. Robert Hemsted, who had obtained it from the workmen. We recovered a jaw, two tibia, and several other bones of the same animal from the bone merchant who had purchased them from an itinerant dealer in such wares. This dealer had bought from the gravel-diggers a barrow-load of these bones for 6*d.*; but we could recover only about a dozen out of a huge heap which he was good enough to have picked over for the express purpose.

A section in Somersham Station-Yard, shows 4 feet of brown angular gravel, and some pits just N. of the station gave the following section:—

	Feet.
Sandy soil - - - - - - - -	3
Fine angular stratified flint gravel - - - -	3½
Yellow Sand, said to be about - - - -	3
Oxford Clay, said to have been reached at a depth of -	15

Other pits a quarter of a mile N. of the church show—

Sandy soil - - - - - - - -	2
Fine angular stratified gravel, with patches of sand and loam - - - - - - -	8
Grey loam and water.	

The skull and horns of *Bos primigenius* were taken in 1877 from the base of this gravel. One of the workmen stated that some years ago a similar lot of bones was found in the pit, also a stone "battleaxe," and that these were sent up to some London Museum.

The small island of Oxford Clay in High North Fen, in which Rumbold Farm stands, is capped by a patch of gravel, small in extent and thickness.

Valley of the Ouse, Lower Terrace.

The town of St. Ives stands on a broad spread of this deposit, which occupies both banks of the river. We have no measurement of its thickness, but it is

doubtless many feet, and it passes in under the alluvium. A mile S.W. of the town a pit 5 feet deep, S.E. of the "Woolpack" Inn, shows it to consist of a fine stratified gravel, with coarser gravel below, containing some large stones, quartzites, &c. From this point the gravel may be expected to thicken considerably towards the river, but the pits just south of St. Ives are in fine chalky gravel to a depth of 3 feet only, when the water-level is reached, checking further operations. There are numerous small pits on the northern bank of the river, several ponds also expose the gravel, which supplies them with an abundance of water.

Some small pits S.W. of Swavesey Church show 3 feet of fine brown angular gravel and sand, and a similar gravel is exposed in some pits south and west of Oxham Fen.

"The Holcrofts," north of Over, occupy another broad expanse of similar gravel, which is seen in many ponds, ditches, and small pits, but the only excavation of any importance is just N.E. of Over, where the pits show 4 feet of fine angular gravel and sand. There are some old pits half a mile N.W. of Willingham, where the gravel is exposed beneath a few inches of soil, consisting entirely of decaying peat, in fact, the "feather-edge" of the Fen.

Over Court, on the left bank of the Ouse, stands on a patch of gravel rising from beneath the Fen; it is seen in a pit north of the road to Holywell.

Bluntisham Fen is skirted on the west and north by banks of valley gravel. A pit near the edge of the Fen, south of Bluntisham, was in fine angular gravel, with horizontal lines of stratification, 5 feet deep. A small pit further east shows 4 feet of similar gravel.

A pit, south of Bluntisham Church, was being worked in 1877 for ballast for the new line of railway (St. Ives Extension), and gave an interesting section 6 feet deep in fine sandy stratified gravel, with a layer of grey clay (2 inches thick) in the middle, enclosing *Bithinia tentacularis*, *Cyrena fluminalis*, *Pisidium*, and *Cardium edule*. There is a thin layer of shell-marl near the top of the gravel.

A small patch of valley gravel, or rather of wash from an older gravel, occurs just north of Newmarket Union House, where a pit shows :—

	Feet.
Brown sandy wash - - - -	2
Light-coloured sand - - - -	3
Flint gravel;	

and a well in the pit touches Chalk about 12 feet from the surface.

An old pit, a few chains N.W. of the Union House, is said to have been in 15 or 16 feet of sand.

CHAPTER X.—RECENT DEPOSITS.

Alluvium and Peat.

There is little to be said regarding the alluvial soil which skirts the banks of the several streams, for it is very seldom seen in section. It usually, but not invariably, rests on gravel, and it varies in depth from a few inches in the higher parts of the tributary valleys to several feet below Cambridge. Some observations on the outlying area of Fulbourn and Wilbraham Fens have already been given (p. 109.)

A good section was, however, seen in the western bank of Byron's pool, near Grantchester, where the face, freshly cut by the floods in 1875, exhibited :—

	Feet.
Black peaty soil - - - - - - - -	1
Layer of black mud with stones at the base, fragments of deer-horn and many shells, such as *Limnea stagnalis, Bithinia tentaculata, Planorbis complanatus, Paludina Listeri,* and *Unio pictorum*	2
Loose gravel, 2 or 3 feet shown.	

North of this, by Grantchester and Cambridge, the alluvium appears to be everywhere underlaid by gravel, but opposite Fen Ditton the river has cut a more recent channel for itself through the Chalk Marl, and the outcrop of the Cambridge Greensand would probably be found under the alluvium about half a mile N.N.W. of Fen Ditton Church.

Beyond this point the alluvium widens out by Milton Fen and Clay Hithe, and finally passes into the broad expanse of the fens towards Upware. On the west these fens run back southward toward Horningsey, Quy-cum-Stow, and Swaffham Bulbeck, but the depth of peat is nowhere very great over these inlets of the fen country, and there is sometimes little more than a turfy soil.

Along the edges of the fen the turf generally rests directly upon Gault or Chalk Marl, as the case may be, but in the deeper portions it is often underlaid by sand or sandy gravel. A strip of such gravel runs under the fen from the neighbourhood of Horningsey north-westward, and may possibly mark the prolongation of the old channel of the Quy-water stream. Again, in Swaffham Bulbeck Fen there is sand or silt in some places, and the following section was seen in a pit near the junction of the "Black" and "White Droveways."

	Feet.
Black peaty soil - - - -	1
Fine yellow sandy silt - - - -	4
Chalk Marl, about - - - -	7

At the other end of the Black Droveway the peaty soil is very full of land and fresh water shells, amongst which *Cyclostoma elegans* is common. This shell also occurs in the Warp, but is not, to our knowledge, found alive now in any part of Cambridgeshire. *Helix lapicida* also occurs at the same spot, but is now very rare in the neighbourhood.

To the northward, in Reach and Burwell Fens, the peat is thicker, and is still dug for fuel in many places.

Remains of prehistoric man, in the shape of flint implements of various kinds, are frequently met with in these fens, and many are described in Mr. Evans' "Stone Implements of Great Britain." Flint and greenstone celts, "with the sides more or less flat, so as to range between Figs. 53 and 58 (*op. cit.*) are of not uncommon occurrence in the Fen country." Rough-hewn flint celts are also not unfrequently found (*op. cit.*, pp. 61 and 68).

It may not be generally known, but it is a fact worthy of record, that cattle left to graze for any time on the fen lands are liable to

a peculiar disease of the throat, termed "ulcers," the remedy for which is removal to higher ground. It is considered, and with much show of reason, that the attacks are induced by some noxious ingredient of the water the cattle consume; this drains into the ditches and ponds from the saturated peat, and must be more or less contaminated by organic matter in a state of decomposition.

On this subject Mr. JENYNS has some interesting observations. He says*:—There is still an abundance of decomposing vegetation in those parts of the Cambridgeshire fens which have not yet been brought under cultivation. Portions of the fen remain unenclosed, and are purposely kept in a partially undrained state for the sake of the peat or turf, as it is locally called, which is dug out in large quantities for firing, and to which the poor in some parishes have a common right. Wherever this is the case the moor is broken up into a number of pits, that speedily become filled with water and aquatic plants. Among the latter are certain species of *Chara* and *Potamageton*, which abound more than any others, and the first of these especially is well adapted for causing a rapid accumulation of vegetable remains at the bottom of the pits, by the constant decaying of the lower part of its stem, while its upper extremity continues to make fresh shoots. From this circumstance there is soon formed a decomposing mass which, as the heat of summer partially dries up the water, is exposed to the atmosphere, emitting a most offensive effluvium. I believe these to be the plants which, during the putrefactive process, mainly contribute to the miasma that arises from the Cambridgeshire fens. . . . . . The peculiar strong odour caused by the decomposing *Chara* in the deeper pits is very obvious on approaching one in summer that is half dried up. . . . This evil, however, is probably yearly becoming less. All the best turf in Swaffham Fen has long since been used up. What is now dug there is of a very inferior quality, and much less profitable for fuel, and from the extent to which drainage has been carried on in recent times the formation of new turf is no longer possible. The time is probably not far distant when the whole moor will altogether cease to be worked for turf, and when it will be found more to the advantage of the owners to have it thoroughly drained and brought under cultivation."

Warp and Trail.

This term, proposed by the late Mr. TRIMMER, may perhaps be taken as a convenient name for the soil immediately underlying the vegetable mould. Mr. TRIMMER says:—"The majority of the soils and subsoils in the British Isles are composed only in part of the débris of the rocks on which they rest, and in part of materials transported from various distances;" the soil thus produced he calls the "warp," or the "warp of the drift."

It appears to us that Mr. TRIMMER would have included under this name that portion which Mr. FISHER subsequently separated under the designation of "trail." We are inclined, therefore, to define warp as comprising all the material between the vegetable mould and the undisturbed subsoil or rock forming the underlying stratum. This would include most cases of trail and rainwash, as well as ordinary soils, which often, as Mr. FISHER has pointed out, extend underneath the peaty or silty clay of alluvial flats.

The depth of such Warp varies, of course, very greatly, but we have not seen any instances in Cambridgeshire where it was more than 5 feet.

* Observations in Meteorology, London, 1858, p. 374; see also the same author "On the Turf of the Cambridgeshire Fens." *Rep. Brit. Assoc.* for 1845, *Section* 5, p. 75.

† *Quart. Journ. Geol. Soc.*, vol. xxii. p. 562.

A good instance of such warp or wash was seen in a trench opened for obtaining coprolites near the river half a mile N.N.W. of Harston, the section being as follows:—

	Feet.
Dark grey soil, about - - - - - -	1
Compacted marly silt, probably rainwash from the hill to the west - - - - - - -	3 to 4
Fine river gravel - - - - - -	1 to 2
Bedded clunch, in place - - - - -	8?

Mr. Fisher, in describing the soil overlying the clunch in the pits between Harlton and Haslingfield, says*:—"The upper portion of the sections usually exhibits from a foot to a foot and a half of soil, which I call, after Mr. Trimmer, *Warp*. In this district it is unusually full of land shells of recent species. Nevertheless the assemblage is not exactly what one meets with living on the spot." He instances *Cyclostoma elegans* as very common in the Warp, but not found alive, also *H. arbustorum* as the commonest *Helix* in the Warp, while now *H. nemoralis* is commoner, and he thinks it likely that drainage and cultivation may have been sufficient to have caused these changes.

Below the warp in these pits is found the marly clay with stones and patches of gravel, which Mr. Fisher calls "trail;" this is without shells, is comparable to the rainwash in the above section, and its average thickness appears to be from 2 to 3 feet.

* *Geol. Mag.*, vol. viii. p. 65.

CHAPTER XI.

THEORETICAL CONSIDERATIONS AS TO THE PHYSICAL CONDITIONS UNDER WHICH THE GLACIAL AND POST-GLACIAL DRIFTS WERE DEPOSITED.

I. *Boulder Clay.*

Having described the various drift deposits in our district we may now offer some remarks on the conditions under which they were formed, and may state the conclusions to which we have been led from the study of their structure and mode of occurrence.

There is no doubt that the Chalk, covered by Eocene beds, once extended over and far beyond the area of the map (Pl. 7), although within its limits not a vestige of the latter now remains.

Professor RAMSAY believes that the *Severn,* after Miocene times, "began to cut a valley towards what afterwards became the Bristol Channel, and established the beginning of the escarpment of the Chalk, which has since gradually receded, chiefly by atmospheric waste, so far to the east. If this be so, then the origin of the valley of the Severn (*i.e.*, the 'beginning of the escarpment') is of immediate Post-Miocene date."*

The escarpment probably had receded to its present position, or thereabouts, by the end of the Pliocene period. During the progress of the partial Eocene submergence and the subsequent re-elevation, the Chalk was subjected to some disturbance, resulting in the formation of many small faults, flexures, and contortions. A considerable flexure of this or a later period probably gave rise, as we have seen, to the formation of the coomb-like hollow, called Wardington Bottom, which now forms an upper extremity of the Cambridge Valley (see p. 83).

Although the escarpment had been cut back to its present position by the close of the Pliocene period, and the land was somewhat submerged during the deposition of the Pliocene beds on the east coast, there are in our area no signs of their present or former existence. For the valleys were not excavated to their present depth by perhaps 50 or 100 feet, and consequently any such deposits that may have been formed therein have long been swept away. For the same reason there are no deposits which can be referred to the earliest part of the succeeding Glacial period; it is, in fact, doubtful whether any were formed within the area. For these may have been excluded from the district by its then height relatively to that at which they occur elsewhere. Indeed we are now inclined to think that the Chalk hills were nearly or quite continuous across the Wash during Pliocene and early Pleistocene times, and that this barrier was not broken through until the period of the Upper Glacial Clay.

Neither, with two possible exceptions (see p. 73), do we find any of the so-called Middle Glacial deposits, which just over the

* "Physical Geology of Great Britain," *Ed.* 3, p. 219.

Chalk escarpment run up to a height of 300 feet or more above the sea, and to at least 200 feet above what must have been the bottom of tbe Cambridge Valley at the time of their deposition. Had such beds been formed we should expect to find them still between the older rocks and the Boulder Clay, at least in some part of the area within which the latter occurs. It cannot be assumed, as in the case of the Pliocene beds that the "Middle Glacial" beds at one time occupied the valley, and were afterwards (but before the Boulder Clay period) removed; yet in no instance do we find the Boulder Clay resting on any other than Pre-glacial formations. This question has already been discussed by one of us, and an explanation of the probable causes which excluded the Lower and Middle Glacial deposits from the Cambridge Valley given in a paper on "East Anglia during the Glacial Period."*

As we have seen (p. 77) the Boulder Clay rests, or has rested, on a surface of older rocks corresponding very nearly with that which now forms the Cambridge Valley, this old surface having been covered by the deposit. As the clay occurs from the lowest to the highest point, the question naturally arises has this old valley been completely filled by a great thickness of Boulder Clay since removed by detrition? We think not, but that the clay was of fairly uniform but not great thickness, perhaps 100 feet or thereabouts, from the ground now occupied by the fens up to and over the Chalk escarpment. The formation of such a sheet of material, spreading alike over hill and valley, involves, we are aware, the existence of conditions very different from those under which extensive deposits are commonly formed.

The total absence of all signs of stratification justifies the exclusion of the ordinary conditions of deposit from water; but we think it shuts out also the theory sometimes advanced of the entire mass of the clay having been dropped from melting bergs of ice. Such hypothesis demands that the clay shall have been ground up into its present unstratified condition, and have received its heterogeneous constituents elsewhere; and, to a limited extent, this has been the case, but the theory of accumulation by icebergs does not explain how or whence the material was derived. Further, we are satisfied that any finely divided matter, so dropped from *floating* icebergs, whether in small or large masses, could not fail to exhibit fine or coarse lines of rude stratification.

It has been forcibly urged that such a clay could and would be formed beneath a sheet of land-ice, and that it would necessarily consist of a mixture of the débris of the various rocks over which the ice-sheet had ground its way. And the fact of the Boulder clay being, to a great extent, everywhere composed of the worked-up ingredients of the formation upon which it rests, lends great apparent support to this solution of the problem; but it has never been shown (so far as we are aware) that a sheet of land-ice does form beneath itself a thick bed of re-assorted material; examples from ice-covered countries of the present day have not been quoted in evidence. On the contrary, it has been observed that where large sheets of ice exist they denude rather than cover up the

* Penning, *Quart. Journ. Geol. Soc.*, vol. xxxii. p. 191.

floor over which they pass and their smoothed and striated beds are rather cited as marks of ice-action. Of course if an ice-sheet erodes the underlying rock, the material resulting from this detrition must be re-deposited elsewhere ; but it is impossible that a sheet of ice should both wear away and cover up a surface at the same time. It has been suggested that such detritus would be re-deposited in the hollows of the surface, while the higher points would alone be striated and ground down ; but if such had been the origin of the Boulder Clay, high and low ground alike would not have been covered by a thick mass of the deposit.

Moreover, it is necessary in seeking an explanation of the origin of this clay to account for the presence in it of boulders of rock derived from a great distance. This can scarcely be ascribed, considering the *local* character of the clay, to the passage of ice over the land between their original site and present resting place. It is due rather to the work of ice-floes or icebergs, although, for the reasons given above, we cannot accept the idea of the clay having been altogether transported and formed by their agency.

We see that the Boulder Clay *has* been ground up into its present unstratified condition, and *has* received its heterogeneous ingredients through some kind of ice-action ; also that it *is*, to a great extent, everywhere composed of the worked-up constituents of the formation upon which it rests. But, for the reasons advanced, we are not prepared to adopt either of the hypotheses above-mentioned, and we venture to suggest that neither will, at least in this area, be found to account satisfactorily for the phenomena.*

"There is, however," as Professor John MILNE has truly said, "another form of ice, which, from its unassuming appearance, although touched on by a few, has apparently taken too low a place in the role of actors with which it plays . . . . this is coast-ice."

"From what I have seen of coast-ice and of its effects. I feel persuaded that it is an agent of at least as great, if not of greater, universality than either glaciers or icebergs, and taken as a whole perhaps also as an agent of equal power. Of the various forms of sea-ice known as 'berg-ice,' 'floe-ice,' 'park-ice,' and the like, the portion I would more particularly draw attention to is that variety which forms a narrow belt along the shore, known in Greenland as the 'ice-foot.'"

"It would appear that in the formation of the ice-foot . . . . . we may have either one or many causes called into operation. . . . . . The ice-foot of Greenland owes its origin to the action of the tides. . . . . . The first frost of the late summer covers the sea with a crust of ice, which, carried upwards along the face of the cliff by the tide, eventually becomes glued to the rocks. It thus grows in thickness with every successive tide until it may reach a height of 30 feet, and sometimes even more, presenting to the sea a bold wall of ice against which the floes grind and crush."

"The blasts of December and January drive the spray high up upon the land, and there it freezes as a cake of ice; day after day and night after night this continues, and the crust grows thicker . . . until at last it is from 2 to 3 feet in thickness. Stones of all sizes, from pebbles to boulders, on which this coating may rest, are now firmly set in an icy maw of ice, and are ready at the first moment to cut and grind a path for themselves.

"This generally goes on until some portion of the northern pack, coming south, meets with an adverse wind and is driven ashore. When we reflect upon the immense mass contained in one of these moving fields of ice, we

* *Geol. Mag.*, Dec. ii., vol. iii. pp. 304 and 403. See also a paper by the same author, "On the Action of Coast-Ice on an Oscillating Area." *Quart. Journ. Geol. Soc.*, vol. xxxiii. pp. 929–31 (1877).

can hardly conceive the energy that is stored within it. Everything has to give way before it, and the coast-ice, with its set of gravers firmly bedded in its base, is pushed high and dry, sometimes as much as 100 yards, back from high-water mark. It is in this way, by the coming in of the northern pack, the rise and fall of the tide, and other causes, that the land-ice is driven ashore, and many of the scratches and grooves so common round the coast of Newfoundland have been made."

"In addition to the work done in scratching and grooving by the coast-ice, it also does much in the transportation of material. When in deep water, chafing along the face of a cliff by its own horizontal and vertical movements, together with its continued force of impact on a heaving swell, it must detach a considerable amount of material. This, together with that which may fall upon its edge from the rocks above, is carried by the coast-ice to a new home.

"The chief agent, however, in the transportation of material is the ice-foot attached to the shore. At low water this freezes to the ground on a shelving shore, and is at once firmly attached to both boulders and stones; when the tide rises this ice, with its cargo, floats and may be carried away. The consequence of these transportive movements is that much material, both boulders and pebbles, are carried out to sea, and then deposited in a manner similar to that which has so often been explained in the case of icebergs. Another consequence is that similar materials are carried from point to point along the coast, and on the disappearance of the ice are left as monuments of its former existence."

"The vast ice-fields which break loose from the frozen regions of the north, and we read of them 300,000 square miles in extent and 7 feet in thickness, are, in their passage south, driven in upon the land, and help to grind the coast line and transport its boulders. . . . . Amongst the inhabitants of Newfoundland the action of coast-ice as a transporting agent is universally recognised, whilst ice bergs in the same latitudes are seldom seen with earthy materials upon them."

Speaking of the "ice-foot" in Greenland, Dr. R. BROWN says :—*

"As the spring and summer thaws proceed land-slips occur, and earth, gravel, and avalanches of stones come thundering down on the ice-foot, there to remain until it breaks off from the coast and floats out to sea with its raft-like load of land *débris*. As the summer's long sunlight goes on, the ice worn by the sea parts with its load; and this may be shortly after its leaving the land, or it may float tolerably far south. . . . . Often fields of ice will float along and, like icebergs, graze the surface of rocks only awash at low tides, *and therefore its action might be mistaken for that of icebergs or land-ice.* In other cases I have known the ice-foot, laden with *débris*, to be driven up by the wind and high tides on to low-lying islands, spits, and shores, piling them with the load thus carried from distant localities."

Again, speaking of ground-ice, which is formed below shallow water on the bottom of the sea, he states that it "often rises to the surface laden with sand, gravel, stones, and seaweed. Sheets of ice, with included boulders, are driven up on the coasts during storms and packed to a height of 50 feet. How easily such sheets of ice, with included sand, gravel, or boulders, may furrow and streak rocks beneath may be imagined."

Lastly, we would adduce the testimony of Prof. YOULE HINDE, who has described the extensive formation of Boulder Clay on the north-east coast of Labrador through the agency of "pan ice," which is derived from bay-ice, floes, and coast-ice; "thus broken ice is pressed on the coast by winds, and the pans rise over all the low-lying parts of the islands, grinding and polishing exposed shores, ... the masses pushed or torn from these surfaces are urged into the sea and rounded into boulder forms by the rasping and polishing pans."†

The foregoing extracts have been reprinted because we are convinced that the agencies therein described are exactly similar to

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* Physics of Arctic Ice. *Quart. Journ. Geol. Soc.*, vol. xxvi. p. 689.

† Notes on some Geological Features of the N.E. Coast of Labrador. *Canadian Naturalist*, vol. viii.

those by which the Great Chalky Boulder Clay of East Anglia was chiefly produced.

The arguments by which we consider the coast-ice theory can be mainly supported are :—(1) The great extent of coast-ice as compared with that of glaciers. "Looking at the Northern Hemisphere only, and comparing all the deeply-indented coast-lines (say that of North America and Greenland, every yard of which is more or less subject to the action of coast-ice) with the portions throwing off glaciers to form bergs, it will be seen that the coast-ice must in quantity be infinitely greater than the glaciers."* Coast-ice is not only of greater extent, but it would act more equally on every part of the coast where it occurs, although its work would gradually decrease in the direction of warmer latitudes. Any product of its action would consequently be more uniform in thickness than that which is glacier-formed and berg-transported; for this must of necessity thin out in every direction from certain maximum points of deposition. The Boulder Clay extends, or has extended, over all the area where it now occurs in mass or in patches, and was of fairly uniform thickness, which causes it to conform so nearly as it does, on the large scale, to the contour-lines of the district.

2. The great uniformity in the characteristics of the clay, which varies as the nature of the deposit on which it reposes; such variations affording another proof of local, as opposed to distant, formation. Wherever exposed the clay is seen to be unstratified, and presents an appearance of having been rolled, jammed, or beaten into its present state, rather than of having been dropped from icebergs, for we might reasonably expect in such a case that the clay would vary quickly according to the difference of the loads deposited, derived from distant sources of formation. There would also be lines of division, not to say stratification, between the freights thus deposited; but no such lines of division and no such sudden changes of material have been observed.

It has been shown that even in this limited area the clay simulates the formation beneath; on the Oxford Clay it can be distinguished from it only in actual section; on the Gault it resembles Gault; on the Chalk it is often nearly white in colour, and is in fact reconstructed Chalk; but in each case it contains boulders of chalk and of other rocks, all from the North; not however as patches of Chalk, of Oolite, or of any other deposit, but *scattered throughout the mass.* Whatever the origin of the clay, the boulders enclosed in it must have been ice-transported (either by themselves or within the mass of the clay); we assume that they were brought by bergs to the area within which the clay was being formed, and that they were afterwards incorporated as component parts of the clay.

3. Fragments of rocks which occur within the area, but at a much lower level, are now found at the higher points, even on the summit of the Chalk escarpment. As an instance of this may be mentioned the phosphatic nodules from the "Cambridge Greensand," which were taken from Boulder Clay on the high ground south of Royston (see p. 75). This lifting of local fragments, which can be cer-

* MILNE, *op. cit.* p. 408.

tainly identified, to much higher ground in a comparatively short distance is work that we conceive scarcely possible to any other agent than coast-ice, acting in the manner previously described (p. 117).

After careful consideration of the evidence, and a study of the clay itself in very many sections, we are convinced that coast-ice has been the main agent in its formation. This has ground down and mixed up the material of the shores subjected to its action, and incorporated with it other material brought by itself from some near locality, or by icebergs from a distance. It has pounded up the mass again and again, rounding the softer pebbles, but making little impression on the harder; and it has by repeated shiftings moved *débris* from the lowest to the highest points now under consideration; and it has been aided in this, it must be borne in mind, by its work being done in a *sinking* area; every part of which in turn was subjected to its influence. Nay, every part has *twice* been acted on by this agency, first as the land was sinking beneath, and again as it emerged from, the waters of the Glacial Sea.

It may be supposed that as the land went down it would be covered, as a sea-bottom, when once below the level of coast-ice influence, with sand, gravel, or stratified clay. Possibly it was so, but any deposits then formed on the surface of the earlier clay would be removed and ground up with other material by coast ice on its emergence. It may be that the beds of sand, gravel, or loam here and there found associated with the clay are trifling representatives of such intermediate deposits, although few would escape, considering how readily they must have yielded to such powerful denuding agency.

After the completion of the M.S. of this memoir, our colleague Mr. SKERTCHLY (firstly in the Geological Survey Memoir on "The Geology of the Fenland," and then in "The Fenland Past and Present," by MILLER and SKERTCHLY) strongly advocated the theory that the Boulder Clay was formed beneath land-ice. Notwithstanding his assertions, however, we are still convinced that the arguments in support of a coast-ice origin have the advantage.

We are pleased now to find that our views on the origin of the East Anglian Boulder Clay are in accordance with those of our Director-General Prof. RAMSAY,* who quotes Prof. YOULE HIND's account of the action of "pan-ice" (coast-ice) and the formation of Boulder Clay and observes that "as the British Islands during the Glacial epoch were more than once much in the same state as the north of Labrador there can be little doubt that some of the British phenomena were produced by the same causes."

2. *Post-Glacial Gravels.*

In this district we have no indications of the greatest depth of the Glacial submergence, but it was probably many hundreds of feet; that it continued for a long period is certain, judging from the thickness of the Boulder Clay. Whatever oscillations of level may have occurred elsewhere during the Glacial period, there are in our area marks of but one, and that a gradual long-continued

* See his "Physical Geology and Geography of Great Britain," Ed. 5. p. 396 (1878).

movement of depression, succeeded by an equally gradual re-elevation.

When this re-elevation began, and as the land rose from beneath the sea, every part in turn, as a receding shore-line, would be subject to the action of the waves and of the ice-foot, the surface of the newly-formed Boulder Clay being "thereby eroded and to some extent re-assorted. A clayey gravel would naturally result, and the whole of the uneven surface of the clay would be more or less covered by such material";* but larger masses would be accumulated on the flats and in the hollows and channels.

We consider the oldest gravels described (pp. 79–81) to belong to this period of emergence, and that they were formed from the waste, partly submarine and partly subaerial, of the Boulder Clay. As the land rose these deposits advanced their edge, constantly following and infringing on the receding zone under the influence of coast-ice, which was, however, at that time much diminished in extent and importance.

As the elevation of the land continued, and when a considerable area had risen above the waves, the action of subaerial agencies would be intensified, so that the detrition of the higher ground would be usually rapid. This detrition was indeed of no ordinary character; extensive denudation was the result, and this has even been taken to indicate a period of excessive rainfall, resulting in the formation of deposits equally abnormal in their development. Mr. A. Tylor has suggested that this should be called the "Pluvial Period,"† and he believes that during this time there were such great land-floods that the previously existing valleys were entirely filled up with beds of gravel, and loam washed in from the high ground along their sides; he further considers that the present rivers have only re-excavated their courses through the immense mass of material thus accumulated.

Prof. Prestwich too has called in the agency of floods to account for some of the appearances presented by the series to which he gives the name of high-level gravels, and other observers have come to like conclusions.

Mr. Skertchly has described gravel on the edge of the Fenland, which he considers to be "a deposit formed by land-floods during excessive rain, which swept over the country irrespective of its natural features, and after those features were formed. "The deposit," he says, "is essentially of local origin, as is shown by the ingredients which constitute its mass, and seems to have been formed during intense floods."‡ He therefore terms it Flood Gravel," and refers to this deposit the gravels which cover the high ground between the valleys of the Little Ouse and the Lark, and which appear to occupy the same position as the gravels we have mapped south of the Lark Valley.

There are evident objections to invoking the agency of abnormal conditions, when those which already exist are equal to the per-

* See "East Anglia during the Glacial Period," *Quart. Journ. Geol. Soc.*, vol. xxxii. p. 195; also "The Post Tertiary Deposits of Cambridgeshire." Cambridge (1878).

† *Quart Journ. Geol. Soc.*, vol. xxiv. pp. 105 and 455, and xxv. p. 58.

‡ The Geology of the Fenland, pp. 195, 208. *Geological Survey Memoir*, 1877.

formance of the work; still we admit that the unusual characters and positions of these deposits point to a peculiar combination of conditions at the period when they were formed. We hope, however, to show that the rainfall of that time need not have been excessive, and to account not only for the torrential action which led to the formation of these so-called "flood gravels," and continued during the deposition of the old river gravels, but also for its comparatively sudden cessation.

We have suggested that the Boulder Clay did not entirely fill the Cambridge Valley, which would have involved a thickness of at least 400 feet over the low ground. On the other hand we think that the land sank, and that the clay was formed along the margin of the sinking area at a fairly uniform rate, resulting in a sheet of the material, which wrapped over high and low ground alike, except at the highest points of the escarpment S.W. of the Cambridge area. The old larger features were thus preserved, minor hollows were of course filled up, but the larger valleys, as such, still existed on the emergence of the land. This being so, it matters not what might have been the actual thickness of the clay, 5 feet, 50 or 100, the result would have been much the same—the rising ground on the north, the escarpment on the south, the low ground between, would all have been covered by a sheet of impervious Boulder Clay.

What would take place now, with our present rainfall on an area so situated? We cannot quote an exactly analogous case; but where high clay lands are found the streams are quickly filled in rainy seasons, and unless the channels are kept in good order the low lands are soon inundated. Those who live on the western borders of the Fen have nothing to fear from the Fen waters, but after heavy storms the water from the high lands rushes down, and thus their lands are "drowned." In a district such as this must have been just after emergence from the Glacial sea, with a continuous covering of *impervious clay*, all the rain falling on the higher lands would make its way quickly to lower levels. The whole rainfall would thus be rapidly collected in the then existing channels, a large body of water therefore would flow along and erode them, producing all the results which have been attributed to excessive rainfall.

In times of rain and storm these streams would quickly rise and flood their banks, producing wide-spread deposits over what were then the lowest grounds, but which are now, through later denudation, many feet above the present alluvial levels. Some of these deposits might therefore be correctly termed "flood gravels," but we do not believe that beds formed in this way were ever so extensive as to "spread all over the country, crossing water-sheds, occupying the highest ground and running down to the lowest."* We cannot but think that when the country has been completely mapped, it will be found that gravels of two or more ages have here been treated as contemporaneous.

While fully prepared to admit the cogency of the evidence brought forward regarding the great volume and velocity of the ancient rivers, in this and in other parts of England, we cannot

* Skertchly, in J. Geikie's "Great Ice Age," Ed. 2.

regard this as any proof of a proportionately great rainfall; we believe, in fact, that a Fluvial Period need not necessarily be a Pluvial Period. Especially we hope to explain the causes by which the present order of things was brought about, and the chief effect of which was the cessation of the undoubted torrential action.

3. *The Physical History and Relative Ages of the River Valleys.*

We now proceed to consider the physical conditions which prevailed in Cambridgeshire during the formation of those gravels which are distinctly of fluviatile origin.

Reviewing the facts brought forward in the preceding pages, regarding the disposition of these river gravels, we may draw some conclusions which have an important bearing on certain points in the physical geology of the Cam Valley, and may gain some idea of the succession of changes which have taken place in the country since the Glacial Period.

It has already been pointed out that the earliest series of loams and gravels in the district, bear witness to the existence of a river-system quite different from the present, and entirely independent of the existing lines of drainage, except in the uppermost parts of the tributary valleys descending from the Chalk Hills. As we trace the oldest series towards the hills, we find that the direction of its branches gradually approximates to that of the present valleys, and that these old river deposits have a recognizable relation to the ultimate valleys and coombs of the Chalk escarpment.

We conclude, therefore, that the outline of the hill districts has not changed within the Recent period so much as that of the lower country, and the plains beyond; that the valleys which now furrow the sides of the chalk hills may be regarded as the ends of the old valleys formed by these ancient rivers, more deeply worn it is true, but still following the original lines. In the lower country great changes have taken place, and an immense quantity of material has been removed by denudation, so that the deposits which once lay in valley bottoms are now found along the ridge tops, and are sometimes cut through by channels of more recent origin, not only so, but it would appear that in one part of the Cam Valley (between Whittlesford and Cambridge) the destruction of ground by the combined action of rain and rivers has been so great that all traces of these ancient deposits have been swept away.

We are now brought face to face with the question, What caused this alteration in the general system of drainage, or in other words, Why have the tributary streams of the Cam deserted the courses which were taken by two of the main affluents of the older river?, that from Wardington Bottom, and that from the neighbourhood of Wilbraham. We must conclude either that there is a considerable period of unrepresented time between the epoch of these ancient rivers and that marked by the formation of the Barnwell and Trumpington series of gravels, or that there are facts which will explain this apparent break without having recourse to such a supposition.

Let us endeavour to picture the country as it probably appeared at the earlier epoch, and to reclothe its surface with those portions of the once *continuous* envelopes which have since been stripped away by denuding agencies. We have reason to suppose that at the commencement of this terrestrial period the mantle of Boulder Clay covered a far greater surface than it does now, and must then have spread far more generally over the ground between the Chalk scarp and the high plateau west of the Cam Valley.

At the time when the water ran along the older lines of drainage, we think that the Gault was not exposed in any part of this valley south of Cambridge, the river Rhee had not yet come into existence, and the Orwell hills, with their capping of Boulder Clay, stretched southwards to Shepreth and Melbourn, the water from their slopes flowing chiefly into the Wardington Valley.

The general direction of the Bourn Valley may have been sketched out at this early period, but looking to the position of the later gravels along the Barton and Grantchester ridge, the surface of the Gault can hardly have been exposed here at any earlier epoch than that to which these gravels belong.

The point at which the ancient gravel series first impinges upon the surface of the Gault is near Gravel-hill Farm, west of Cambridge, and though the southern branch of the river may have cut down to the Gault about St. John's Farm, it is not likely to have done so more to the south. Lower Chalk, capped by outliers of Boulder Clay, then covered the sites of Trumpington, Shelford, and Harston; the few springs then existing could not have been like those now thrown out in the Lower Chalk, but were in different positions, and were of necessity much weaker, the river being mainly supplied by water flowing off the hills along the channels which we have already indicated.

It has already been pointed out that as long as the slopes above these valleys were covered with Boulder Clay, a very large proportion of the rainfall would be carried off along the surface; consequently the volume of the rivers would then have been far greater than that of the present streams, and especially during seasons of flood: but as denudation proceeded the area of bare Chalk would be much larger, and a proportionally greater quantity of rains absorbed into the ground, to be partially thrown out again as springs when it had reached a much lower level.

What would be the result of this greater absorption of the rainfall as the Boulder Clay was gradually cut back to the slopes of the higher ground, and a larger area of bare Chalk exposed? The effect on the system of drainage would be two-fold:—(1.) Less water would flow directly into the old channels, and thus the rivers would gradually lose their power to keep those channels open; (2.) The water absorbed by the Chalk would be thrown out again in springs, and as these springs increased in volume their position would greatly affect the courses and directions of the streams.

We believe, therefore, that it was this important alteration in the absorption of the rainfall which produced the first great change in the direction of the main lines of drainage; also that the alteration in the position of the springs, consequent upon their recession and the gradual lowering of the line of saturation under the Chalk hills, was the principal cause of the subsequent changes in the course of the Cam and its tributaries.

It is probable that on the outer slopes of the Gog-Magog Hills there were in early times but two strong springs, where now there are four, and that the position of the one was somewhere between the Nine Wells and the Cherry Hinton spring (probably about the site of the Cambridge Railway Station), while that of the other, represented now by the Fulbourn and Wilbraham springs, was somewhere north of Fulbourn. It is a significant fact that the probable positions of these two springs are opposite two gaps in the ancient gravel-ridge, through which run two lines of more recent river deposits. As regards the gap at Quy-water Bridges its probable mode of formation is pointed out in the description of Wilbraham and Fulbourn Fens (p. 108), and there can be little doubt that the process there indicated was only a repetition of what had taken place over the site of Cambridge at a much earlier date.

As the old river from the east declined in volume and strength, the power of the springs proportionally increased, and changes occurred in the valley of the river from the south, which was ultimately diverted into the channel marked out by the gravels of the Barnwell series. The waters of what we may call the Gog-Magog spring would be intercepted by this stream, and the result would be the formation of a lake or lake-like expansion of the river as in the cases of the Wilbraham (p. 108) and Hauxton (p. 105) lakes.

We have evidence of such lacustrine conditions in the character of the deposits at Barnwell; the loamy marl bed, (with its plant remains, its many land and fresh water shells, and its well preserved mammalian bones) is the slowly accumulated deposit of a quiet expanse of water, the home of *Chara* and delicate molluscs, and the drinking place of elephants and other beasts; moreover, the succeeding beds of sand and marl, with like contents, bear witness to the continuance of like conditions for a considerable time. Gradually, however, the lake silted up, and its overflow slowly worked a wider gap through the obstructing ridge in front; eventually, when the Chalk had been worn through and the Gault exposed, erosion would be more easy and rapid, so that the river has since continued to flow through the gap thus made between Barnwell and Castle Hill.

In the outspread of loam, sand, and gravel about Histon and Impington we have evidence of another lake-like expansion of this river where it was blocked

by the ridge of the Lower Greensand. Deflected north-eastward by this it seems to have flowed by Landbeach and Denny Abbey towards Thetford and Ely, where it may have entered the ancient bay of the Wash.

The subsequent changes in the valley south of Cambridge appear to have been brought about by the tendency of all rivers in wide valleys to alter their channels, influenced in this case by the changes in the position of the springs as their points of outflow were shifted farther back. Some of the episodes which occurred during this period, represented by the intermediate series of gravels, have been recorded in the description of these deposits (p. 101); we now confine ourselves to tracing more fully the history of the Rhee Valley.

The origin of this valley, *i.e.*, the cause that determined the existence of the hollow which subsequently became a valley, was probably the existence of a strong spring thrown out at the base of the Totternhoe Stone, when its outcrop lay over the present site of Harston. As this spring receded southwards, a valley began to be formed which received the drainage of the surrounding hills; minor springs from the horizon of the Melbourn Rock likewise came into existence along its sides, and determined the position of tributary water-courses. The strongest of these seem to have lain in the valley which leads to Foulmire, and the larger part of the surface drainage being probably directed into this channel, that which is now a tributary seems at first to have been the most important stream in the district. It ultimately received the whole drainage from that part of the Chalk escarpment which in earlier times had contributed its supply to the waters of the older Wardington river; the materials of the more ancient deposits being carried down and re-arranged in the newer valley, forming the gravels, of which remnants still remain near Foulmire, Foxton, and Harston.

The further extension, however, of this Wardington stream was limited by the line of the Upper Chalk escarpment, the recession of which was, and still is, carried on only at a very slow rate. In the meantime the recession of the strong spring thrown out by the Totternhoe Stone had given rise to the commencement of the tributary valley, along which the Rhee now flows, and this rapidly became an important affluent, cutting off the drainage from the clay-capped hills on the north and receiving the waters of the springs which came into existence on the south. The stream at length cut down to the Gault, and then two fresh elements were introduced among the forces which were shaping this new valley: the access of water thrown out from the nodule-bed at the base of the Chalk, and the character of the underlying clay which yields to fluviatile erosion more rapidly than the Chalk.

Eventually, therefore, a long and wide valley was excavated, which continued to increase in length and width long after the Wardington stream had ceased to be an important branch, for we have seen that the southward extension of the latter was stopped by the Chalk scarp, but the westward extension of the Rhee Valley progressed till the sources of the springs were cut back to their present position near Ashwell, with only a narrow watershed between them and the sources of the river Ivel.

All this could not have taken place until the Boulder Clay had been completely removed from the district by an earlier system of drainage; moreover, the absence of gravel throughout this portion of the Rhee Valley, from Ashwell to Barrington, is proof of its recent and rapid excavation, for we should expect the removal of Boulder Clay to have resulted in the production of extensive beds of gravel. We conclude, therefore, that this part of the valley, though now occupied by a river which rivals that in the Chesterford Valley, and drains an area of about 40 square miles, dates in its commencement from a newer period than that in which the Barnwell gravels were deposited (see ante, p. 94.)

CHAPTER XII.—ECONOMICS.

This district, in common with the whole of East Anglia, is very bare of mineral or other geological wealth, whilst the counties to the north and west abound in iron and building stones. We find in Cambridgeshire scarcely any valuable mineral productions but the coprolites. The country has a purely agricultural character, relieved to a small extent only in the lower-lying parts by lands under grass for dairy and grazing purposes.

The Oxford and Kimeridge Clays, in the north-western corner, are used, but not to a great extent, for brickmaking, the largest manufactory being in the former, near the town of St. Ives.

The Lower Greensand, which elsewhere affords ironstone and phosphate in small but workable quantities, here consists mainly of sand and loam, but has not been worked for many years so far as we are aware, even for brickmaking.

The Gault yields a fairly good brick clay, which has been, and still is, extensively used around Cambridge for drain pipes and tiles, as well as for bricks; the latter are hard and durable, being much better in quality than in appearance.

"*Coprolites.*"

The base of the Chalk Marl consists, as has been shown, p. 27, of the well-known "Cambridge coprolite bed," which for several years has been worked to a considerable depth throughout the area where it occurs, affording employment to large numbers of workmen.

The first "diggings" are said to have been about the Eversdens, and in the neighbourhood of Horningsey, the bed at first being worked back from its outcrop to a depth of a few feet only. The cuttings were afterwards reopened and carried back to about 16 feet deep, beyond which depth they could not then be worked at a profit. But at the present time, from a cheaper method of working, from the greater value of the phosphate, or from both causes combined, it answers to extract the bed even 24 or 25 feet beneath the surface. Attempts have been made to get out the mineral without removal of the overlying marl, by driving tunnels along the bed, in fact by the methods similar to those adopted in mining; but the base of the marl follows the general rule of dipping in under the higher ground, so that the water within it, held up by the Gault beneath, has hitherto presented an insuperable difficulty to this plan, but we are inclined to think that by collecting and working out a sufficient number of data, spots might be found where tunnelling for coprolites could be carried on at a cheaper rate than 25 feet of overlying earth can be removed.

The method by which the phosphate nodules are obtained consists in digging a vertical trench, with one or more stages, according to the thickness of the Chalk Marl which has to be removed. Many of the pits are 24 to 26 feet deep, and worked in three stages of 8 or 9 feet each. The vertical face is cut away in great slices by driving wedges and crowbars into it at a little distance from the edge, and the material so thrown down being cast out of the trench,

the nodule bed thus exposed is removed to the washing mill, where the coprolites are separated from their matrix of marl and glauconite.

The mineral-bearing bed is itself of small thickness, perhaps 10 inches may be taken as a fair average, and only one-tenth of this is phosphate, the bulk consisting of marl and sand. Therefore the actual deposit of phosphate is equal to a thickness of only an inch over the area where the bed is known to exist. Supposing the depth of the diggings to be 16½ feet or 200 inches (which is below rather than above the average), 200 cubic inches, or 200 cubic yards, of earth have to be removed for every cubic inch or cubic yard of the mineral obtained.

A cubic yard of phosphate weighs somewhere about two tons, so that the cost of "getting" a ton of the mineral equals the cost of removing 100 cubic yards of earth. This, with the levelling and re-soiling of the field, washing the material, cartage, plant, superintendence, &c., varies from *4d.* to *5d.* per yard, or from *33s.* to *40s.* a ton for the phosphate obtained.

The royalty is usually paid not as so much per ton, but at prices per acre, varying from 100*l.* to 150*l.*, frequently more than double the value of the land, as such, excluding the minerals. A bed of coprolite, equal to an inch in thickness over an acre of ground, would yield 134 cubic yards, or say, 270 tons of phosphate. If the present average price paid per acre for the right of "fossil-digging" may be taken as 135*l.*, the royalty amounts to 10*s.* a ton.

The field to be worked is given over to the contractor for a stated time, within which he extracts the coprolites, fills in and levels the pits, restores the top soil, and leaves the surface of the field very much as it was before; and its fertility is generally improved rather than deteriorated by the process.

At the top of the Chalk Marl comes the Totternhoe Stone, in which are some large quarries, still open, but which were worked much more extensively in former times. The stone was much used for building, especially in churches, and it is still employed for the same purpose to some extent, but not in important structures (see p. 43).

In the Chalk generally are many pits where the rock is excavated and burnt for lime, some of the beds being much better suited to the purpose than others just above or below them. At Linton there is a pit where certain suitable beds of chalk are quarried and tunnelled for the manufacture of whiting.

The flints from the Chalk are used for road-making and mending, also for building walls and houses, all external angles being built in brick or stone. For inferior buildings the flints, with other pebbles, are used just as found, thus producing an uneven face to the wall; but for churches and important buildings some are split through the centre and built in so that the black and nearly flat fractured surface shows on the exterior. Sometimes devices are sunk in buttresses or other stone work, and neatly filled in with dressed black flint; some fine specimens of this kind of work are found in Cambridgeshire.

Agriculture.

Speaking of the chalk land east of Swaffham Bulbeck the Rev. L. Jenyns says*:—"These lands are very good for wheat, and that especially grown on the chalk hills in the vicinity of Burwell is generally more forward than in other places, and the earliest in the market. Much corn is likewise now grown in the reclaimed portions of the fen, but it is liable to be mildewed

* Observations in Meteorology, pp. 367, &c., 1858.

in wet seasons and is always comparatively late. The time for cutting wheat at Swaffham Bulbeck, on an average of 12 years, I have found to be the 30th of July; but in some hot and dry seasons it has commenced as early as the 16th."

As regards climate, he says:—"Cambridgeshire must have improved in this respect. The extent to which drainage has been carried on in modern times can hardly have failed to render the climate less humid. Thousands of acres which were formerly more or less under water, at least during the winter, have been reclaimed in this way and brought into cultivation; the fertility of the soil being greatly improved by a top dressing of clay (Gault), dug up from underneath the moor. Crops of oats are usually first sown, and these after a time are succeeded by wheat."

The Boulder Clay as a rule, but not invariably, supplies an excellent dressing for many kinds of land, a fact discovered and turned to account long ago, if the many old pits in it may be accepted as evidence. As it is made up of the detritus of many and various rocks, and usually contains much chalk, it rapidly disintegrates by exposure to the weather, and it can scarcely fail to improve the fertility of the soil over which it may be distributed.

This clay generally makes a good soil, especially for corn, and (to those who know the cause of its productiveness) the repugnance of many farmers to allowing their ploughs to go down to it is most unaccountable. But they will not, in many parts even now, allow the "raw earth" to be turned up if they can help it; and yet there could be no more sure means of improving their land, if done gradually and with discretion. This prejudice is, however, beginning to give way, and will rapidly disappear before the extension and the excellent results of steam cultivation. There are some parts in which the sudden introduction of deep ploughing has been temporarily the reverse of beneficial; in some others it perhaps has been permanently so. But in by far the great majority of instances, especially on Boulder Clay, the deep stirring of the subsoil, the consequent drainage and exposure of more material to atmospheric influences, has produced, or will produce, great additional fertility.

The deposits which rest on the Boulder Clay at the higher levels, although not extensive, are useful in some of the districts where they occur; the loams being dug for brick-making, the gravels for road-mending. The "ancient river" gravels are as a rule too full of chalk to be much used for repairing roads, but the more flinty portions and the large stones are used for that purpose, as, for instance, from the large pit N.W. of Newmarket.

The more recent gravels are very largely dug in the town and neighbourhood of Cambridge, near St. Ives, and elsewhere, being used for railway ballast as well as for road-making.

The soil of the Fenland is highly productive, and is mostly under cultivation; the branches of fen up the main valley pass gradually into the ordinary alluvial soil, which makes excellent pasture. The marshes, or strips of alluvium, are subject to sudden floods, the water from the surrounding high lands being headed back by want of passage room where they discharge into the washes of the fens.

Water Supply.

It has been stated that the thickness of the Oxford Clay in this part is not certainly known, we cannot, therefore, assert to what depth a boring would have to be made to reach the underlying more permeable strata. But we are convinced that if once the clay were pierced, an abundant supply of water, rising nearly or quite to the surface (according to the site of the boring), would at once be obtained.

In both the Oxford and Kimeridge Clays are bands of limestone, nodules, or septaria, along which water sometimes percolates, in most cases very slowly, but wells have been made in which fair springs from this source have been met with. There is no certainty of getting water from these bands, as in thewells at Conington and Bluntisham (pp. 159, 167,) a depth of 300 feet was reached without success; but in one at Redhill, a farm west of Conington, a good

spring was met with at a depth of 12 feet. Such a source of supply would, of course, be available for a limited consumption only.

The Lower Greensand is usually found to be an excellent water-bearing formation, but its capabilities in this respect are probably much greater where it lies beneath the Gault than at its outcrop.

Where the Lower Greensand is reached by boring through the Gault in this area, an abundant supply of water is invariably found. Not always directly the latter formation is penetrated, although there may be sand directly beneath it, but at no great distance below a "rock" is pierced, from which the water rises frequently to a height of some feet above the surface of the ground. Borings at Harston, Whaddon, and Wendy may be mentioned as instances where iron pumps have been erected over the bore-holes, the water being constantly discharged through the spouts in unvarying quantity and temperature.

The coprolite workings are supplied with water by boring into the Lower Greensand, large quantities being necessary for washing the matrix away from the "fossils." Indeed, were it not for the abundant supply obtainable at slight cost by these borings, the coprolite industry could never have been so profitably developed.

The Gault, like the Jurassic Clays, affords no springs of its own worth mention, but its surface, when overlaid by Chalk Marl, holds up the water that has percolated through the latter, and this constitutes what is locally called the "fossil spring," from its occurring at or in the bed which encloses the "coprolites." This is the spring which prevents tunnelling for "coprolites" being carried on with advantage.

The Chalk here, as elsewhere, is pre-eminently a water-bearing formation, any wells carried down to the line of saturation being invariably supplied. In this area, where the Chalk comes to the surface, the line of saturation is naturally low down on the formation, being quite at its base along the boundary. As the Chalk dips down the line rises, not relatively only as the Chalk base falls, but actually beneath the higher ground. Until the Chalk passes in under impervious Eocene beds or Boulder Clay, it is necessary for all wells that depend on a supply from below the line of saturation to be dug down to it, as the water would not rise in a boring. It is only when the line of saturation is depressed by an overlying impervious stratum that this result can be obtained.

The line of saturation almost invariably rises beneath high ground in a Chalk area, because the rain which falls on the surface percolates downwards, and feeds the sources of supply as quickly as the water is drawn off by the springs and streams of the district. As the water-level falls, and the hydrostatic pressure lessens, the springs and streams fall off, as it rises they increase; thus a general balance is maintained, the height of the line rising above the spring before it can counteract the friction of the water passing through the rock. The line, therefore, has a definite and constant relation to the main and minor valleys of a district, abnormally affected in some instances by the dip of the beds. A good instance of this is furnished by the Gog-Magog Hills, where a synclinal dip depresses the water line by throwing out the splendid springs which supply the town of Cambridge.

We have been enabled to work this point out in a detailed manner through the kindness of Mr. H. Tomlison, C.E., Engineer

to the Cambridge Waterworks Company, who has furnished us with the particulars of many wells in the neighbourhood. From these we have constructed two nearly parallel lines of sections, Figs. 2 and 3, Plate 5, running along the flanks of the Gog-Magog Hills, and connected them by a cross section (Fig. 1, Plate 5). Wells have been dug at all the points indicated to a few feet below the line of saturation, and these show it to be as represented by the continuous lines *a, a,* in the diagrams.

It will be seen that the water-level rises generally under the higher parts of the surface, from N.W. to S.E. along the longitudinal sections; and it has a tendency to rise from Fulbourn Mill towards the Hills Farm, as well as from Stapleford Mill towards Heath Farm in the cross section. But a sudden local depression occurs, the greatest amount of which is beneath the highest ground of the Gog Magog Hills, where it might be expected to be relatively high, and to follow the dotted lines *b, b,* in the sections. The line of greatest depression coincides with the line of hills, and passes from Copley Hill, through Vandlebury, west of the Quaker's Charity Farm, towards Cherry Hinton.

There is no doubt that the Chalk here lies in a synclinal hollow or trough, the inwards dip from each side having mainly contributed to the formation of the hill by preserving its beds, while those on either side were removed by denudation. The broken lines represent the lines of division of the Lower Chalk, dipping towards the escarpment in the longitudinal sections and in the cross section forming synclinal troughs beneath the Gog-Magog Hills.

It will be seen that there is a great correspondence between the cross section of the larger of these troughs and that of the line of saturation, although the latter under normal conditions would differ from the former in being higher rather than lower along the central line. There is probably some connexion between them, of which we believe the following to be the true explanation.

The Totternhoe stone, at the top of the Chalk Marl, holds the water that has percolated down to it through the overlying permeable chalk, as is shown by the line of springs which frequently follow its outcrop. The stone is here, in common with the other beds, thrown into a trough, along the bottom of which water would flow somewhat more freely than elsewhere. We have shown that the line of depression (which coincides with that of the hills) extends towards Cherry Hinton, where there is one of the finest springs in the country. This spring, where the trough runs out to the surface of the ground, throws out (owing to that circumstance) an undue proportion of water, thus permanently lowering the line of saturation along the synclinal axis where the water moves most freely.

Water, even permanent springs, may be met with in fissures in the Chalk before reaching the line of saturation, but it is always most uncertain; indeed the whole thickness of the Chalk may be penetrated without finding any great quantity of water. But there are generally some indications, especially in wells that are dug to any depth, which, if observed in connexion with the dip, structure, and general conditions of the beds, may lead to the desired result.

The Boulder Clay is sometimes slightly permeable, and wells

sunk in it, which fill slowly with soakage water, are the sole sources of supply of many villages in the district. The water is generally very hard, but otherwise not of bad quality.

The Gravels, where resting on clay, are, of course, water-bearing, and they supply most of the towns and villages situated upon or near them. The water they yield would be excellent but for the risks, almost certainties, of pollution by drainage. We have tested many samples of such waters and always found them more or less contaminated.

It is easy to understand that wells would be sunk in such deposits wherever a supply of water was required, or near each house in the towns and villages. But one fails to see why much should have been made of springs, where, through some local condition of the beds, water that has percolated through the gravel and sand of a graveyard is thrown out! Three such cases occur within our area, one at Hadstock, where the spring is enclosed by brick walls, and the water is highly esteemed by the villagers. It may be, however, that the difficulty of drawing and fetching water from the deep wells at the neighbouring farms has some influence on the meed of praise bestowed upon that from the spring.

Another instance is at Somersham, where a brick arch, with an iron gate, has been in former times erected over a spring within the precincts of the old Bishop's palace. The palace has been razed, but the spring, with its protecting arch has been preserved. Yet it is inevitable that some at least of the water must have percolated through the gravel on which the adjoining graveyard stands.

In an analogous case an arch has been erected over a spring, and an inscribed brass-plate built in, to hand down to posterity the name of the benefactor! The water here is thrown out at the junction of Oxford Clay with gravel, in a low corner of the churchyard at Holywell, and is therefore subject to peculiar risk of contamination.

This spring in the churchyard, or "Holy Well," as it was doubtless called, must have given its name to the village; and we find many other instances in this area in which the names are due to some physical peculiarity. There are Fenny Stanton and Long Stanton, both villages or "towns" on deposits of gravel or "stone," Fenny Drayton (Dry-town) and Dry Drayton, Fen Ditton and Wood Ditton, or Ditch-end, one being at each termination of the "Devil's Ditch."

APPENDIX A.

PALÆONTOLOGY.

By R. Etheridge, F.R.S., L. and E., F.G.S.

1. General Account of the Palæontology of the Different Sub-Divisions of the Chalk.

In preparing the lists of Fossils and Appendix to this Memoir much attention has been bestowed upon the naming and distribution of the species obtained by our collector, Mr. H. Allen, in the area under description. No less than 43 localities have been searched, collected from, and recorded in the text under the following divisions, horizons, or zones:—

Lower	1.	The Cambridge Greensand.
	2.	„ Chalk Marl, from 7 localities.
	3.	„ Totternhoe Stone, from 6 localities.
	4.	„ Zone of *Holaster subglobosus*, from 5 localities.
Middle	5.	„ Melbourn Rock, from 6 localities.
	6.	„ Zone of *Rhynchonella Cuvieri*, from 5 localities.
	7.	„ „ *Terebratulina gracilis*, from 6 localities.
	8.	„ Chalk Rock, from 4 localities.
Upper	9.	„ Zone of *Micraster cor-bovis*, from 5 localities.

1. *Cambridge Greensand.*

The Geological Survey has not collected largely from the Cambridge Greensand, that being quite unnecessary in the face of such materials gathered together and named in the Woodwardian Museum.

The list of fossils given on p. 30, and numbering 65 species, has been compiled by Mr. Jukes-Browne from sources other than those of the Geological Survey. No less than 47 species of Invertebrata have been obtained from the matrix of the Coprolite or Phosphatic nodule beds in the neighbourhood of Cambridge. The fossils generally referred to the Cambridge Greensand are far more numerous, but most of these are believed by Mr. Jukes-Browne to have been derived from the Gault. An analysis of the whole fauna will be found in Mr. Jukes-Browne's paper upon "The Relations of the Cambridge Gault and Greensand,"* in which he discusses the age of the so-called Cambridge Greensand, and compares its fauna with the Vraconian of Prof. Renevier, and also with that of the Gault of Folkstone and Buckinghamshire.

There can be no doubt about the close relationship between the fauna of the Cambridge Greensand (excluding the derived fossils), and that of the Chalk Marl; the two doubtless form one palæontological zone, about 50 per cent. of the Invertebrata being common to both. The following species and varieties have been founded on specimens obtained from the Cambridge Greensand, and have not been met with elsewhere. Some of these may therefore be considered as characteristic of this bed.

Anomia transversa, Seeley.	*Rhynchonella lineolata*, Phill.
Lima ornata, Ether.	*Cidaris gradata*, Seeley.
Ostrea cunabula, Seeley.	„ *Sedgwickii*, Seeley.
„ *lagena*, Seeley.	*Echinocyphus impressus*, Seeley.
Plicatula minuta, Seeley.	*Goniophorus lunatus*, Ag. var. *Minutus*, Seeley.
Onchotrochus Carteri, Duncan.	*Salenia Woodwardii*, Seeley.
Pharetrospongia Strahani, Sollas.	

Terebratulina striata, var. *triangularis*, Ether, is also characteristic from its abundance at this horizon, though it also occurs in the overlying marl. It is remarkable that *Rhynchonella lineolata* has not been obtained from any other bed in the Upper Cretaceous Series except this and the Red Rock of Hunstanton, where one or two specimens have been found.

R. Martini has not yet been detected in the Cambridge Greensand.

* *Quart. Journ. Geol. Soc.*, vol. xxxi. pp. 256-316 (1875). Supplementary Notes in vol. xxxiii. p. 485 (1877).

I must, however, notice the series of fossils collected by us from the 8 other horizons or zones, and from 44 localities.

2. *Chalk Marl.*

The seven following localities were collected from: Kingston, Harlton, Hauxton Mill, Madingley, Swaffham, Reach, Burwell (Victoria Quarry).

From these 7 quarries 21 species were obtained, the individuals of most being abundant, the number of Lamellibranchiata and Brachiopoda however predominating; in the former groups 5 species were collected, in the latter 8. Only one Cephalopod (*Ammonites varians*) has been found. An analysis of the 21 species gives their distribution through the 7 areas as follows:—Kingston, 8 species; Harlton, 12; Madingley, 11; Hauxton, 8; Swaffham, 6; Reach, 11; Burwell, 9.

Two species of Fish; 1 Cephalopod; 5 Lamellibranchiata; 9 Brachiopoda; 3 Echinodermata; and 2 Annelida. The two chief groups, the Lamellibranchiata and Brachiopoda, are equally distributed through all the quarries, *Plicatula inflata* and *Terebratula semiglobosa* occur in all the localities. The table at page 42 shows the distribution of the 22 species. *Rhynchonella Martini* is common in the Chalk Marl, and seems to take the place of *R. lineolata* of the Cambridge Greensand.

3. *Totternhoe Stone.*

From this zone, which is better defined physically than palæontologically, the Survey has collected 43 species; in addition to these I have added a supplementary list of 42 species from the Woodwardian Collection, chiefly from the famous quarries of Burwell; these include the 12 new species and varieties, also from the Woodwardian Collection, described by myself in this Appendix.

The six localities searched and collected from in this Zone are:—Harlton, Haslingfield, Orwell, Cherry Hinton, Fulbourn Cutting, and Burwell.

Thirty-eight of the 43 species occur at Burwell, every form being in the Woodwardian Museum. The only species in the list named not represented at Burwell are *Cidaris dissimilis, Onchotrochus serpentinus, Holaster subglobosus,* and forms of *Beryx,* and *Lamna.* The Fauna known to us from this Zone embraces the following:—Fish, 7 species; Cephalopoda, 17; Gasteropoda, 8; Lamellibranchiata, 26; Brachiopoda, 9; Echinodermata, 7; Crustacea, 5; Annelida, 3; Actinozoa, 3; or a total of 85 species.

To the Fauna collected at Cherry Hinton and Burwell I have added 7 new species and 5 varieties, but these were in the Woodwardian Collection, and we were allowed by Prof. Hughes to select, describe, and figure them fo the present Memoir. They are the following:—

Scalaria fasciata, Ether.
Anomia papyracea, D'Orb., var. *Burwellensis,* Ether.
Avicula filata, Ether.
„ *dubia,* Ether.
Inoceramus convexus, Ether.
„ „ var. *quadratus,* Ether.
„ *latus,* Mant., var. *Reachensis,* Ether.
Lima echinata, Ether.
Ostrea curvirostris, Nilss., var. *inflexa,* Ether.
Pecten fissicosta, Ether.
Terebratulina gracilis, Schloth., var. *nodulosa,* Ether.
Pinna tegulata, Ether.

all these, with others, are described further on.

The species collected by the Geological Survey were distributed through the localities as follows:—Harlton and Haslingfield, 15 species; Orwell, 14; Cherry Hinton, 15; Fulbourn Cutting, 11; Burwell, 38.

The supplementary list of 42 species from Burwell obtained from the Woodwardian Collection embraces an important series of forms, and shows the wealth of species contained in the Totternhoe Stone from this one locality; those collected by us from Burwell bring up the number to 85 species.

A comparison of the list of fossils on p. 49, with that of the Zone of *Holaster subglobosus* shows that comparatively few species are *confined* to the Totternhoe Stone, and that the greater number of those which are most abundant individually, range into the overlying beds; this renders it a matter of doubt, as to whether the Totternhoe Stone can be regarded as a separate

division or zone on strictly palæontological grounds; there are, however, many species that appear to be confined to the Totternhoe Stone.

The Cephalopoda are a distinctive feature in the Totternhoe Stone, many making their first appearance in this grey sandy chalk. The constant presence and abundance also of certain Brachiopoda (*Rhynchonella Mantelliana*, *R. grasiana*, *Kingena lima*) is significant, also *Pecten orbicularis*, although these are not absolutely confined to it. It is Burwell that yields the rich fauna of the zone. The Woodwardian Collection contains nearly every form. The Totternhoe species quadruple in number those in the preceding Chalk Marl, as well as possessing a distinctive facies in the groups, many new forms appear, *Pinna tegulata*, *Pecten fissicosta*, *Lima echinata*, &c., and varieties of *Terebratulinæ*. A comparison of the Burwell species with those found in bed 5 of the Folkstone section given by Mr. F. G. H. PRICE,* exhibits great resemblance. The sudden appearance of so many forms in the succeeding zone clearly show a great change of life over the same area at the time of deposition; it is also worthy of notice that *Holaster subglobosus* has not been found at Burwell or Cherry Hinton, only in the basement nodule bed at Shepreth. The nodular variety of *Terebratula gracilis* is almost confined to this horizon, as well as a large form of *Micrabacia coronula*, those in the Cambridge Greensand being a different variety of this coral.

4. *Zone of Holaster subglobosus.*

This palæontological horizon is here used in a more restricted sense than by Dr. BARROIS (see table, p. 21). We have collected from the following five localities in it:—Shelford Clunch Pit, Shelford Limekiln, Cherry Hinton, Eversden, and Pit N.N.E. of Orwell.

From these quarries 40 species have been determined from a large series collected by Mr. ALLEN. The following numbers show how unequal is the distribution of life through certain parts of the Chalk; but as most of the species are rather of a deep sea character, we should expect both prolific and barren areas.

The Shelford Clunch Pit yielded 11 species; Limekiln, 23; Cherry Hinton, 26; Eversden, 11; the Pit N.N.E. of Orwell, 14. *Holaster subglobosus* occurred plentifully at the first three localities, but was not found in the other pits which were richer in Brachiopoda; these numbers would probably be greatly increased by more prolonged collecting.

No Fish were found in the last two localities, and the Cephalopoda are chiefly confined to the Orwell Quarry.

The 40 species fall under the following groups:—Fish, 6 species; Cephalopoda, 4; Lamellibranchiata, 13; Brachiopoda, 7; Echinodermata, 7; Annelida, 1; Crustacea, 2.

The species of *Holaster* giving its name to this zone has a very important bearing upon the distribution of a definite and well determined form over a very large area. Its vertical range in the southern part of England and the northern part of France, according to Prof. HÉBERT, is considerable, including the whole of the Chalk Marl and Grey Chalk of England. Whether we can separate this zone in England into the four subdivisions as proposed by BARROIS, is questionable. It is true we have two species of *Ammonites* (*A. Rhotomagensis* and *A. varians*, occurring here with the Urchin; *A. varians* also occurs in the Chalk Marl at Reach and in the Totternhoe Stone at Burwell, but we have not found it above the zone of *Holaster subglobosus*; a far more complete search must be made for species through these lower divisions of the Chalk before we can correlate even the Cambridge, Bedfordshire, and Hertfordshire sub-divisions with those of the London Basin, much more with those of the north of France; but HÉBERT and BARROIS, by their researches over the last area, have done more to clear up the distribution of life through the Chalk than any other Palæontologists.

5. *The Melbourn Rock.*

Only 15 species have been collected from this horizon, and from the following localities:—Litlington, 7 species; Royston, 6; Melbourn, 25; Harston, 9; Shelford and Cherry Hinton, 7; Swaffham Bulbeck, 4.

These 15 species are thus distributed:—Fish, 5; Cephalopoda, 2; Lamellibranchiata, 4; Brachiopoda, 4. No Echinodermata, Annelida, Crustacea, or

* *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 431.

Actinozoa seem to occur in the Melbourn Rock, and, looking at the paucity of species as well as groups, we may believe that the sediment was not favourable to the conservation of animal remains. *Rhynchonella plicatilis* and a variety of *Ostrea vesicularis* occur in every quarry. The Fish remains were only in the form of teeth, vertebræ, and coprolites; the typical form of *Belemnitella plena* occurs at Royston, Melbourn, Harston, Shelford, and Cherry Hinton.

6. *Zone of Rhynchonella Cuvieri.*

This division of the Middle Chalk (with few flints) corresponds to the zone of *Inoceramus labiatus*, of Barrois.

The species of *Rhynchonella*, giving its name to the zone, from its small vertical distribution, is very abundant at every locality except Wilbraham, where it has not been observed; a more diligent search in the railway cutting would doubtless discover it there also.

This zone is poor in species, if we may judge from the collection made from the five localities, only 14 being procured by Mr. Allen, viz.:—Fish, 1 species; Lamellibranchiata, 3; Brachiopoda, 6; Echinodermata, 3; Annelida, 1. From Stanmoor Hall pit, 3 species were obtained; from Babraham, 10; Little Trees Hill, 4; railway cutting near Wilbraham, 3; and Mistleton Hill, 9.

The Brachiopoda greatly predominate in this horizon, especially at Babraham, where all the six species occur, the characteristic shell *Rhynchonella Cuvieri* being also present in four out of the five localities, and *Terebratula semiglobosa* in three of the five. It is evident that we are but imperfectly acquainted with the fauna of this and the preceding division, but small as is the number of species known in these horizons, still two new forms of Echinoidea occur, *Echinoconus globosus* and *E. subrotundus*, and with these *Inoceramus mytiloides*, *Rhynchonella Cuvieri*, and *Terebratulina gracilis* have reached their maximum development.

Mr. Jukes-Browne, in a note to me descriptive of this horizon, remarks that Prof. Hébert long ago indicated the abundance of *Inoceramus labiatus* in the Turonian of D'Orbigny, and that Dr. Barrois employed its name to designate the lower part of this division, proposing at the same time to consider the upper beds as the zone of *Terebratulina gracilis*. He also states that "certain forms of this little Brachiopod are very abundant in, and perhaps confined to, this portion of the Middle Chalk, but occur also in the lower zone, and *Inoceramus labiatus* is equally common in both;" he believes, therefore, that the two zones will ultimately be distinguished by different species of ammonites, as already pointed out by Dr. Barrois.

Fragments of another Inoceramus seems also to be abundant here; this I have figured as the *I. problematicus* of D'Orbigny (Plate 3, Fig. 10–11).

7. *Zone of Terebratulina gracilis.*

This division of the Lower Chalk is immediately below the Chalk Rock, is about 150 feet thick, and agrees in position to that assigned to it by Barrois in France and this couutry; the species *T. gracilis* which gives name to the beds, and also *T. striata* occur only in the lower division of the zone, and were collected from the three localities in the lower beds, whilst those in the upper beds have not produced any. The result of our collecting has been 25 species, from 7 localities: Worsted Lodge, Mutlow Hill, and Missleton Hill (all in the lower beds); Linton, Westley Waterless, and a pit near Dullingham Station (all in the upper beds); 8 of the 25 species are confined to the lower division, 12 to the upper, and 5 are common to both. The faunal distribution through the quarries in the lower and upper divisions is as follows:—Worsted Lodge, 10 species; Mutlow Hill, 8; Missleton Hill, 9; Linton, 8; Westley Waterless, 11; pit near Dullingham Station, 6; and Carleton Grange, 5.

The Echinodermata and Brachiopoda appear to have abounded in this region, 6 genera and 8 species of the former being collected by Mr. Allen, together with 7 species of Brachiopoda, 7 species of Lamellibranchiata (all monomyarian), 1 Coral, and 1 Protozoa complete the number. The individuals of the above three chief groups were abundant, the Ventriculitidæ and Protozoa generally are very sparingly distributed through the Chalk of Cambridgeshire, one genus only (*Ventriculites*) being determined in all collections made, and only one

species (*V. mammilaris*) occurs in this zone. *Terebratulina gracilis* var. *lata* is the *T. gracilis* occurring in and determining this horizon; the species *T. striata* being much more sparingly distributed; *Cidaris septrifera*, *Cyphosoma radiata*, *Holaster planus*, and *Micraster cor-bovis* occur only in the upper beds of the zone, while *Echinoconus subrotundus* is confined, as far as we know, to the lower division.

8. *Zone of the Chalk Rock.*

This thin but well defined bed is characterised in this area by the abundance of *Holaster* (*Spatangus*) *planus*, which also determines this horizon in Buckinghamshire, Hertfordshire, Berkshire, &c. It is a constant zone throughout the greater portion of the northern part of the London Basin, dividing the Middle from the Upper Chalk, or occurring at the top of the Middle Chalk as now recognised (formerly called the Lower Chalk). It is also characterised by the presence of several Gasteropoda, but they chiefly occur in the form of casts.

We have collected from six different localities on this horizon; individual specimens are tolerably abundant, but only 24 species have rewarded the search in this area. The localities examined are as follows:—Reed and Barkaway (yielding 17 species, including the new form *Rhynchonella Reedensis*); Great Chesterford (yielding 8 species); Carleton Grange (4 species); Westley Waterless, No. 1 (10 species); Westley Waterless, No. 2 (15 species); and Stetchworth (8 species).

Terebratula semiglobosa and *Ter. carnea* appear to occur at all the localities, the *Micrasters* at most of them, *Ananchytes ovatus* at three, and the characteristic *Holaster planus* at four. Only two species of Cephalopoda appear amongst the series collected, *Ammonites Prosperianus* and *Scaphites æqualis*, see table of distribution, p. 128, and the former of these is as characteristic of the rock as the above-mentioned echinoderm.

The fauna of the Chalk Rock is somewhat peculiar, doubtless physical conditions greatly influenced the development and distribution of life. A few species seem to be almost confined to this division; two of these, however (*Rhynchonella Reedensis* and *Holaster planus*), occur also in the upper part of the underlying zone, but have not been found above it in this area, notwithstanding the careful search made by Mr. Allen. The new form of *Rhynchonella* (*R. Reedensis*) may be only a variety of either *R. Cuvieri* or of *R. plicatilis*, its variation being due to the circumstances under which it lived, but no such variety makes its appearance in any lower beds, and well marked *R. plicatilis* occur with it in the Chalk Rock.

9. *Zone of Micraster cor-bovis.*

This zone forms the base of the white Chalk with Flints or true Upper Chalk, and is equivalent to the lower portion of the Senonian of D'Orbigny, with its characteristic *Micraster cor-testudinarum*; at present we have not detected the typical form of this species in our Upper Chalk, *Micraster cor-bovis* or some variety of *M. cor-testudinarum* being its representative. Dr. Barrois gives as characteristic and typical localities for *M. cor-testudinarum* Cuckmere Haven, in Sussex, Stockbridge, Winchester, and Pangbourn. The small difference between this species, as figured by Goldfuss, and *M. Cor-bovis*, or even varietal forms of *M. cor-anguinum* may mislead us; its recognition, therefore, as a typical zonal form in this area must be deferred until the characteristic species has been found and well determined.*

We have collected from the following localities in this division of the Upper Chalk:—Chesterford and Saffron Walden (9 species); Balsham Limekiln (9 species); Balsham, N.N.E. of (9 species); Stitchworth (6 species); Westley Waterless (4 species); together they have yielded 18 species illustrating the following groups:—Lamellibranchiata, 3 species; Brachiopoda, 4 species; Echinodermata, 7 species; Polyzoa, 2 species; Protozoa, 1 species; Actinozoa, 1 species.

The individuals were numerous, *Micraster cor-testudinarum ?* (var.) occurred in all the localities, *M. cor-bovis* and *M. cor-anguinun* in four. Balsham also yields

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* Since writing the above Dr. Barrois has forwarded to me a specimen of *M. cor-testudinarum* obtained by him at Cuckmere Haven, Sussex.

3 of the 4 Brachiopoda, 3 of which are confined to that locality. No other group but the Echinodermata occurs at Westley Waterless, the 3 species above-named, which are also common to all localities, and *Cyphosoma radiatum*, which is also found at Balsham.

With regard to the grouping of these zones into larger divisions, and the grounds for establishing a Middle Chalk, Mr. JUKES-BROWNE has sent me the following observations :—

The Palæontological Relations of the Lower and Middle Chalk.

In this Memoir we have proposed a triple division of the Chalk, and have shown that in what has hitherto been called the Lower Chalk there exists a band of rock possessing peculiar lithological characters, and forming an horizon as marked and distinct as that of the Chalk Rock above. This band we have identified with the bed of marl containing *Belemnites plenus*, which has been found in so many sections in the south of England, and has been described by DR. BARROIS* and Mr. F. G. H. PRICE.†

The beds of Chalk above and below the horizon differ somewhat in their lithological characters, but still more markedly in their fossil contents; an examination of the two faunas has indeed revealed such great differences that the change in the forms of life assumes the importance of a palæontological break in the series. The desirability of the classification proposed is thus strikingly confirmed.

Out of the 90 named species of Invertebrata‡ which have been obtained from the Lower Chalk of Cambridgeshire (as now defined), only eight have actually been found in the beds above the Melbourn Rock; seven more are known to have a wider range, but no less than 74 have apparently died out during the interval between the deposition of the Lower and the Middle Chalk; the following is a list of these forms :—

CEPHALOPODA.

Ammonites cenomanensis, *D'Arch.*
" Lewisiensis, *Mant.*
" Mantelli, *Sby.*
" navicularis, *Mant.*
" rhotomagensis, *Defr.*
" varians, *Sby.*
" " var Coupei, *Brong.*
Belemnites plenus, *Blainv.*
Nautilus Deslongchampsianus, *D'Orb.*
" elegans, *Sby.*
" pseudoelegans, *D'Orb.*
Turrilites costatus, *Lam.*
" Scheuchzerianus, *Bosc.*
" tuberculatus, *Bosc.*
Scaphites æqualis ? *Sby.*

GASTEROPODA.

Cerithium ornatissimun, *Desh.*
Dentalium majus, *Gardner.*
Scalaria fasciata, *Ether.*
Solarium dentatum, *Desh.*

LAMELLIBRANCHIATA.

Anomia papyracea, *D'Orb.*
Avicula filata, *Ether.*
" dubia, *Ether.*
" gryphæoides, *Sby.*
Exogyra haliotoidea, *Sby.*
Inoceramus convexus, *Ether.*
" " var. quadrata, *Ether.*
" latus, var. Reachensis, *Ether.*
" striatus, *Mant.*
Lima aspera, *Mant.*
" echinata, *Ether.*
" globosa, *Sby.*
Ostrea acutirostris, *Nilss.*
" curvirostris, *Nilss.*
" frons, *Park.*
" Rauliniana, *D'Orb.*
Pecten elongatus, *Lam.*
" fissicosta, *Ether.*
" orbicularis, *Sby.*
Pholadomya decussata, *Sby.*
Pinna tegulata, *Eth.*
Plicatula inflata, *Sby.*
Radiolites Moretoni, *Mant.*
Spondylus æquicostatus, Ether.

* Recherches sur le Terrains Cretacés Supérieurs, *Lille*, 1876.
† *Quart. Journ. Geol. Soc.*, vol. xxxiii.., p. 431.
‡ The species peculiar to the Cambridge Greensand and named on p. 132, are not reckoned in this number.

BRACHIOPODA.

Argiope megatrema, *Sby.*
Kingena lima, *Defr.*
Rhynchonella grasiana, *D'Orb.*
* „ Mantelliana, *Sby.*
* „ Martini, *Mant.*
Terebratula biplicata, *Sby.*
Terebratula squammosa, *Sby.*
„ sulcifera, *Morris.*
Terebratulina gracilis, var. nodulosa, *Ether.*
„ striata, var. triangularis.

ANNULOSA.

Glyphæa cretacea, *M'Coy.*
Necrocarcinus Woodwardi, *Bell.*
Enoploclytia brevimani, *M'Coy.*
„ Imagei, *Mant.*
Pallœga Carteri, *Woodw.*
Pollicipes arcuatum, *Darwin.*
„ unguis, *Sby.*
Serpula annulata, *Sby.*
„ rustica, *Sby.*
Vermicularia umbonata, *Mant.*

ECHINODERMATA.

Cidaris Bowerbankii, *Forbes.*
„ Dixoni, *Cotteau.*
„ vesiculosa, *Goldf.*
Discoidea cylindrica, *Lam.*
„ subucula, *Klein.*
Hemiaster Morrisii, *Forbes.*
Holaster lævis, var. trecensis, *Leym.*
„ subglobosus, *Leske.*
Pseudodiadema.
Pentacrinus Fittoni, *Austen.*

ACTINOZOA.

Micrabacia coronula, *Goldf.*
Onchotrochus serpentinus, *Duncan.*

It may be objected that the Middle Chalk of Cambridgeshire has not been searched so completely as the lower beds, and consequently that the requisite data for such a comparison have not yet been obtained. This is to some extent true, and only 30 species have hitherto been found in this division; yet there can be little doubt that it does not possess so large and varied a fauna as that of the Lower Chalk; moreover, we are fortunately able to point to other areas which have been still more thoroughly examined, the result in every case being to reveal a striking contrast between these two faunas.

Thus, in his description of the chalk between Folkestone and Dover,† Mr. F. G. H. PRICE has catalogued 95 Invertebrates from the Chalk Marl and Grey Chalk; only three of these range upwards into the overlying beds, viz., *Goniaster mosaicus*, and the ubiquitous forms *Ostrea vesicularis* and *Terebratula semiglobosa.* From the two zones forming the Middle Chalk he records 19 species, including the three above mentioned; thus though some additions will probably be made to the latter fauna, it is clear that here also the two assemblages are very different, and that the break is marked by the extinction or migration of a very large number of species.

In the Isle of Wight Dr. BARROIS mentions 41 species as occurring in the Chalk Marl and Grey Chalk, and 18 species in the two zones of the Middle Chalk; only three being common to both divisions. In Sussex, he quotes 24 species from the Cenomanian and 23 from the Turonian (near Lewes) and there is not one species common to the two lists.

Again, Mr. CALEB EVANS‡ records 20 species from the Grey Chalk of Sussex, and 30 species from those beds which appear to represent our Middle Chalk, and only three species range from one group to the other.

Finally, DR. BARROIS' researches in the north of France enable us to make a thoroughly reliable comparison between the faunas of the Cenomanian and the Turonian, because large collections have been made from each division. From the Lower Chalk (zones of *Holaster subglobosus* and *Belemnites plenus*) he

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* These occur doubtfully in the zone above (of *Rhynch. Cuvieri*).
† *Quart. Journ. Geol. Soc.*, vol. xxxiii., p. 431.
‡ On some Sections of Chalk between Croydon and Oxstead. Paper printed by *Geol. Assoc.*, 1870.

has in his various papers catalogued a total of 102 Invertebrates; in his recent memoir "Sur le Terrain Cretacé des Ardennes"* he gives a list of fossils from the Turonian of the eastern part of the Paris Basin, which numbers 83 species exclusive of the Fish. Only 15 species are common to the two faunas, so that the interval beween the two periods seems to have witnessed the extinction of 87 species and the introduction of no less than 68 new forms. We may at any rate assume this calculation to be an approximination to the truth.

This sudden and complete change of life can hardly be attributed to any sudden or local alteration in the physical conditions, for there is very little difference in the character of the sediment constituting the beds above and below the Melbourn Rock.

We are, therefore, forced to conclude that there is here a break in the continuity of the Chalk, marking a long lapse of unrepresented time, during which the conditions of existence throughout the whole province underwent very considerable but gradual alteration, producing a corresponding effect upon the life of the province.

It is even possible, as Dr. Barrois has suggested, that in Cambridgeshire a certain amount of erosion and destruction of previously formed deposits went on during this interval. He remarks upon the diminution in the thickness of the zone of *Belemnites plenus* in this area compared with its development in the south of England and north of France, and considers that "these uppermost Cenomanian beds were more or less denuded at the invasion of the Turonian sea, and that the *Belemnites* which they contained are now found rolled and remaniés at the base of the Turonian." The structure of the Melbourn Rock and the rolled lumps of chalk which it so frequently contains are decidedly confirmatory of this supposition.

The Middle Chalk of Cambridgeshire appears, therefore, to be marked off by lines of erosion, one at the base of the Melbourn Rock and the other at the top of the Chalk Rock, so that these two layers must be included within the division. That the formation so constituted possesses a fauna that is essentially peculiar to it has already been established, but we desire to draw special attention to two classes of animals which are represented by such different species in the Lower and Middle Chalk respectively that they are of themselves sufficient to distinguish the two faunas. These two groups are the Cephalopoda and the Echinodermata; of *Ammonites* alone the Lower Chalk contains a large number of species, but not one of them has yet been found in the Turonian or Middle Chalk, which likewise possesses its own peculiar assemblage. The following is a list of the commoner species in each of these assemblages:—

Ammonites of the LOWER CHALK.	*Ammonites of the* MIDDLE CHALK.
Ammonites rhotomagensis, *D'Orb.*	Ammonites nodosoides, *Schl.*
„ cenomanensis, *D'Orb.*	„ rusticus, *Sby.*
„ navicularis, *Mant.*	„ Woolgari, *Mant.*
„ Mantelli, *Sby.*	„ carolinus, *D'Orb.*
„ Lewisiensis, *Mant.*	„ peramplus, *Sby.*
„ varians, *Sby.*	„ var. Prosperianus, *D'Orb.*
„ falcatus, *Mant.*	

The Echinoderms form a still more interesting study, for some of the Cenomanian genera do not occur in the Turonian, and of those genera which do range upwards the representative species are for the most part different. It is observable, however, that the different species of certain genera appear to form correlative series, and to bear that amount of resemblance to one another which we should expect if the newer had been gradually developed from the older species under the influence of those causes which Darwin terms "natural selection."

* *Ann. Soc. Geol. Nord.*, t. v., p. 442.

The following is a list of the principal species belonging to these two faunas :—

Lower Chalk.	Middle Chalk.
Holaster subglobosus, *Leske.*	Holaster planus, *Mant.*
„ trecensis, *Leym.*	„ coravium, *Lam.*
„ nodulosus, *Goldf.*	Cardiaster granulosus, *Goldf.*
Hemiaster Morrisii, *Forbes.*	„ pygmœus, *Forbes.*
Epiaster crassissimus, *D'Orb.*	Micraster breviporus, *Ag.*
Cidaris Bowerbankii, *Forbes.*	„ cor-bovis, *Forbes.*
„ vesiculosa, *Goldf.*	Cidaris subvesiculosa, *D'Orb.*
„ dissimilis, *Forbes.*	„ ? dissimilis, *Forbes.*
„ hirudo, *Sorig (rare).*	„ hirudo, *Sorig.*
Pseudodiadema ornatum, *Goldf.*	Cyphosoma simplex, *Forbes.*
„ variolare, *Ag.*	„ radiatum, *Sorig.*
Echinocyphus difficilis, *Ag.*	Echinoconus subrotundus, *Mant.*
Peltastes clathratus, *Ag.*	„ globulus, *Desor.*
Salenia Clarkii, *Forbes.*	Saleniagra nulosa, *Forbes.*
„ Austeni, *Forbes.*	„ mespilia, *Woodw.*
Discoidea subucula, *Klein.*	Discoidea minima, *Ag.*
„ cylindrica, *Lam.*	„ Dixoni, *Forbes.*

Many of the species which appear in the upper part of the Middle Chalk range up also into the beds above the Chalk Rock, so that the greater palæontological break appears to be that at the base of the Melbourn Rock; the following species, however, seem to have died out in England before or during the formation of the Chalk Rock :—

Inoceramus Brongniarti, *Sby.*	Discoidea Dixoni, *Forbes.*
„ mytiloides, *Mant.*	„ minima, *Desor.*
„ problematicus, *Schlot.*	Echinoconus globulus, *Desor.*
Spondylus striatus, *Sby.*	„ subrotundus, *Mant.*
Rhynchonella Cuvieri, *D'Orb.*	Holaster planus, *Mant.*
Ammonites (all the species mentioned above).	Cyphosoma simplex, *Forbes.*
Cidaris dissimilis, *Forbes.*	Cardiaster pygmœus, *Forbes.*
„ hirudo, *Sorig.*	Salenia granulosa, *Forbes.*

Echinoconus subrotundus is a form which Prof. Forbes long ago recognised as being "chiefly confined to a lower geological horizon than *E. albogalerus*, and characteristic of the hard or lower chalk."* The same may be said of the allied but distinct species *E. globulus*, and both appear to be most abundantly developed in the lower part of the zone of *Terebratulina gracilis*. The universal presence of these and other Echinoderms in precisely homotaxial beds is a remarkable proof of the constancy of these palæontological zones over the Anglo-Parisian province, and of the uniformity of the life-conditions that prevailed during this period.—A. J. J-B.

2. Description of New Species.

Gasteropoda.

Scalaria fasciata, Etheridge. Pl. 1, Fig. 1.

Shell elongated or attenuated, whorls probably 12 or 14 (10 seen), strongly costated, ventricose, and reticulated. Costæ nodular where the concentric striæ pass over them, number of ribs or costa doubtful, probably 14 or 15. Concentric striæ numerous, well defined, about 18 on each whorl; between each rib there are 6 or 8 faint vertical thread-like lines, giving the intercostal or depressed spaces a reticulated appearance; at the base of each whorl, or along the sutural line or constriction an elevated rugose cord-like band (*fascia*) is present, composed of wavy lines, so that there is no sharp or well-defined depression between the whorls.

* *Mem. Geol. Surv.* decade iii. pl. viii.

This shell appears at first sight to be the species so well figured by GOLDFUSS,* we are now, however, able to add a few more (6) volutions to MUNSTER'S figure, and also show other characters not present in the German shell. The sutural band is not present in the figure of *Fusus costato-striatus*, given by GOLDFUSS, even in a cast the place of this cord-like band would be conspicuous. MUNSTER'S specimen or figure, like our own, does not possess the last or body whorl; this is to be regretted, as we are therefore left without evidence as to the nature of the mouth, consequently also the true name of the genus is doubtful. Probably the last whorl was ventricose, and possessed a nearly round mouth, if so, it would certainly ally it to the genus Scalaria, its resemblance to that genus is striking, and but for the sutural band, should determine it to be *Scalaria dupiniana:* that species, from the Gault of Folkstone and France, it is not, however, but very closely allied to it.

Whether this shell is really a Fusus, or a form of Scalaria, it is really difficult to say, it certainly closely resembles the *S. dupiniana*† D'Orb, but that shell possesses no band or along the suture or junction of the whorls. The absence of the body whorl and mouth is unfortunate; reference to GOLDFUSS' figure‡ shows great similarity, but the whorls in our specimen are more ventricose, being more constricted along the sutures, thus resembling the Gault form, but the profound or deep sutures in the latter shell at once removes it from the Gault shell. *Scalaria albensis,* D'Orb, and *S. Gaultina,* D'Orb.|| possess bands along the sutural line, but whether belonging to the top of the one or base of adjoining whorl, am not able to say. This would probably be a specific character.

Locality, Burwell (Totternhoe Stone).

Collection, Woodwardian Museum, Cambridge.

Turbo gemmatus, Sow. Dixon, Geol. Sussex, p. 384, t. 27, f. 26.

This shell is figured by SOWERBY in the above work, probably it is also the species figured by S. WOODWARD, in the outline of the Geology of Norfolk in 1833, under the name of *Cirrus striatus;* the figure is so bad that strict corelation or identification seems hardly justifiable; it is, however, more than probable that they are the same. *Turbo gemmatus* appears to be characteristic of the Chalk Rock, and has been collected from most of the localities where that zone is exposed.

LAMELLIBRANCHIATA.

Pecten fissicosta, Etheridge. Pl. 2, Figs. 1, 1a., and Pl. 3, Figs. 1, 1a.

Shell elongated, longer than wide, wings or auricles unequal, valves strongly costated, or ribbed, costæ broad slightly arched or gently rounded, straight and about 15 in number, lines of growth strongly marked, especially so with age, appearing like two or three shells one within or placed upon the other. The costæ, or ribs of the upper half (ligamental portion) or two-thirds of the shell have a line, or depression down the centre, giving them the appearance of being double; this character is not seen in the newer or last formed part of the valve; auricle of right valve deeply notched for bissal sinus, and waved in structure. Hinge line straight, umbo pointed, intercostal or depressed spaces half the width of the raised ribs or costæ, and marked by slightly wavy lines crossing at an angle of about 50°, occasionally they are zig-zag between the 3 or 4 of the central ribs, these lines also cross some of the costæ at the same angle, on the anterior and posterior sides of the shell, but appear absent on the middle costæ, which are more flattened than the side ribs, and delicately lined longitudinally.

The auricles differ greatly, that of the left, or byssal side, being strongly waved, deeply notched, and having corrugated parallel lines of growth.

This well-marked shell seems to have been overlooked, probably owing to its rarity, or the want of good examples from other areas; the Cambridge shells from the Totternhoe Stone of Cherry Hinton and Burwell are, however,

* Petr. Germ. t. 171, f. 18.
† Pal. Fran. terr. crét., vol. p. 54, t. 154, f. 10–13.
‡ Petr. Germ. t. 171, f. 18, *loc. cit.*
§ Pal. Fran. terr. crét., vol. 2, p. 51, t. 154, f. 4, 5.
|| Pal. Fran. terr. crét., vol. 2, p. 56, t. 154, f. 14–16.

admirably preserved, and enable good characters to be given. Through the liberality of Professor HUGHES, we are enabled to figure both valves of this species (with many other fossils) from the fine collection in the Woodwardian Museum. We possess the left valve of the same shell from the Lower or Grey Chalk of Dover, but badly preserved; it is doubtless the Cherry Hinton and Burwell form.

The left valve of this specimen differs in many respects from the right, especially so as regards the costæ which are much flatter, and possesses the impressed line or depression along the middle of the rib to the extremity or ventral margin of the shell, as well as in the condition and structure of the wings.

Hinge line straight, wings unequal, anterior largest and nearly double the size of the posterior, marked with well-defined inclined costæ, the ribs are flatter and less rounded and elevated than in the opposite or right valve; again, the impressed line down the centre of the costæ is constant to the completeness of the shell in this valve, this and the flatness of the ribs readily distinguishes one valve from the other.

Localities, Burwell, Cherry Hinton, and Orwell (Totternhoe Stone).

Collection, Woodwardian Museum, Cambridge.

Pinna tegulata, Etheridge. Pl. 1, Fig. 2.

Shell elongated, attenuated, wedge-shaped, umbones extremely pointed or acute; whole shell appearing to have been externally cancellated or angularly fimbriated throughout, the fimbriæ arching over the costæ, being acutely pointed in the centre of the costæ. Numerous fine lines appear to have occurred between the chief fimbriæ. We figure the shell on account of its acute form and peculiar costal markings, trusting that better specimens or evidence may be obtained as to its external characters.

The acutely-pointed tegulate, or toothed character of the fimbriæ, seems peculiar to this shell. This character is not present either in *P. tetragona,* Sow., *P. morcana,* D'Orb., or *P. decussata,* Goldf. The nearest form to our shell is *Pinna quadrangulam,* Goldf.?* but in that species the median line is falcate or arched.

We have only an interior from which to diagnose the above characters, but the impression left on the chalk by the exterior of the shell and other characters are sufficient to enable me to determine much of its original state, certainly as to what it is not, for no European shell appears to resemble our form sufficiently well to refer it to. No Indian or American species has any affinity with the Burwell shell either as to form or marking.

Locality, Burwell (Totternhoe Stone).

Collection, Woodwardian Museum, Cambridge.

Inoceramus latus, Mant. var. *Reachensis,* Etheridge. Pl. 1, Figs. 3, 3a.

Shell thin, flat, or very slightly inflated, regularly concentrically furrowed; umbones very acute, the umbonal region rugose and wavy, hinge line straight about two-thirds length of shell. Shell structure extremely thin, concentric lines of growth very regular and sharply defined, intercostal striæ or finer lines of growth also very fine and arranged in shallow bands, which gradually and equally increase in width with the growth of the shell, the concentric depressions being regular and smooth.

One shell resembles *I. latus,* Mant., from the chalk of Sussex, also *I. mytiloides,* Mant., both these species are figured by MANTELL and GOLDFUSS, but with neither of them can I correlate our shell. *I. regularis* D'Orb., is also closely allied, but the sharpness of the ridge, acuteness and rugosity of the umbonal region, and increased length of the hinge line removes it from that species; and but for the sharpness or thinness of the hinge line and depth of the shell it may be the *I. cuneiformis,* D'Orb. After referring to all available or figured species I am obliged to refer it to *I. latus,* Mant., as the nearest species, and give it the varietal name *Reachensis,* where, as at Burwell, it appears to be somewhat plentiful.

Localities, Burwell (Totternhoe Stone) and Reach (Chalk Marl).

Collection, Woodwardian Museum, Cambridge.

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* Goldf. Petr. Germ. t. 127, f. 8.

Inoceramus convexus, Etheridge. Pl. 2, Figs. 6, 6a.

Shell, with both valves ventricose and expanded, nearly smooth or delicately concentrically ridged; hinge straight about half the length of shell, containing numerous shallow vertical ligamental pits (30 or more). Umbones pointed, contiguous, slightly curved, and lines of shell growth coarser or more rugose here than on the body of the shell. Right valve rather the smallest.

The shell, although resembling *Ino. striatus*, Mant., and some varieties of *I. Lamarckii*, Park., is nevertheless distinct from either, being more ventricose, more finely striated concentrically, less rugose, and shell structure thinner. I fail to find any shell agreeing with our Burwell form, therefore give it the above name. The more numerous cartilage pits, narrow hinge area, and extremely close growing concentric striæ removes it from known Inocerami. A slight ridge on the anterior side of the shell gives it some resemblance to Lima, but this character is much more strongly marked in the variety *quadratus* from the same locality, described below.

Locality, Burwell (Totternhoe Stone).

Collection, Woodwardian Museum, Cambridge.

Inoceramus convexus, Ether., var. *quadratus*. Etheridge Pl. 2, Fig. 7.

The specimen figured on Plate 2, Fig. 7, may be only a variety of Fig. 6 (*I. convexus*), but the strong ridge and large area on the anterior side is here a significant character, provided it be a normal condition of the shell. Shell ventricose, as broad as long, deep. Hinge-line probably nearly the length of the shell. Umbones pointed, sub-anterior, slightly curved, and more rugose or concentrically furrowed than the rest of the shell; lines of growth regular and equidistant. The concentric sulci or depressed areas shallow, distant, and wide; external layer of shell moderately thick.

The hinge line, ligamental pits, and posterior end are unfortunately not preserved in this shell, much of the wing being broken away; it must, however, have been of considerable dimensions, giving the shell when living a very inequilateral appearance.

In some respects this shell resembles *I. Brongniarti*, Sow., which again may be taken for *I. Lamarckii*, MANTELL. This latter name, as applied to the figure in MANTELL's Sussex, t. 27, f. 1, or Geol. Sussex, Dixon, New Ed. t. 63, f. 1., shows the area and length of hinge line, with hinge pits, 26 in number (not seen in our shell). This want in the Burwell shell is unfortunate, and leaves us in doubt as to the affiliation with the Sussex form. The large anterior area, strong ridge, and concentric striæ ally it closely to *I. convexus* of which I believe it to be a variety. I name it *I. convexus*, var., *quadrata*.

Locality, Burwell (Totternhoe Stone).

Collection, Woodwardian Museum, Cambridge.

Inoceramus (*Mytilites*) *problematicus*, Schloth., Petrif. p. 312.
Mytiloides labiatus, Brongniart, Geol. des Env. de Paris, t. 3, f. 4, p. 215.
Inoceramus, D'Orb., Pal. Fran., Terr. crét, vol. 3, p. 510, t. 406.
Plate 3, Figs. 9, 10, 11.

Many specimens of a species of Inoceramus have occurred to our collector Mr. ALLEN, which are either the young of some mature form, or a small but new species; none of those in our possession are perfect, some mere fragments, one or two, however, lead me to believe that they are young forms of *Inoceramus problematicus*, Schloth., D'Orb.,* *I. mytiloides*, Goldf.,† both of which appear to me to be the same species. *Inoceramus* (*Mytiloides*) *labiatus*, Brong., *loc. cit.*, certainly is the same species; but the two figures (Nos. 1 and 2) given by D'Orb. on his plate (*loc. cit.*) most closely resemble our specimens, so much so that I am not justified in giving our fragments a new name. Young specimens of *I. regularis*, D'Orb., would also much resemble those we possess.‡ The French shells occur in the middle beds of the Étage Turonién, which equals our Lower Chalk; and therefore much upon the same horizon.

* Pal. Fran. terr. crét., p. 510, t. 406.
† Petr. Germ. t. 113, f. 4.
‡ *Loc. cit.*, t 410.

These fragments are figured as having value upon their stratigraphical distribution through the Chalk.

Localities, Missleton Hill near Fulbourn, and Chalk Hill, near Babraham (from Middle Chalk, zone of *Rhynchonella Cuvieri*).

Collection, Museum Practical Geology.

Lima echinata, Etheridge. Pl. 2, Figs. 2, 2a. 2b.

Shell very inequilateral, elongated, as broad as long, somewhat rhomboidal in form, strongly ribbed, or costated. These costæ are 24–26 in number, and ornamented with two or three lines of closely set tubercles or blunt spines, one central row, another on each side; these give the entire shell a tuberculated appearance; hinge line straight, umbo rather acute, area under left wing small and smooth, intercostal spaces deep and occupied by strongly marked transverse lines.

I am unacquainted with any *Lima*, British or foreign, at all approaching this shell; in shape it resembles *L. Cottaldina*, D'Orb., and *L. parallela*, D'Orb., and in ornamentation the ribs resemble *L. Cenomanensis*, D'Orb., and *L. granosa*, Goldf., but none of these species are so tubercular or nodulose, and the intercostal striæ differ from all.

Locality, Burwell and Cherry Hinton (Totternhoe Stone).

Collection, Woodwardian Museum, Cambridge.

Lima ornata, Etheridge. Pl. 3. Fig. 2, 2a.

Shell obtusely rounded, somewhat rhomboidal, umbo probably tumid; ribs or costæ 16, roundly elevated, and all ornamented by longitudinal lines composed of small tubercles, intercostal spaces wider than the costal, or ribs, especially so on the posterior part of the shell where they are greatly developed, and densely decussated, or semi-tuberculated, the tubercles being arranged in longitudinal lines; umbones obscured or eroded; anterior portion of shell rounded, posterior end or side truncated.

I have sought all sources, British and foreign, but fail to find any shell resembling this species either in shape or markings; it was collected from the Cambridge Greensand, unfortunately the hinge area is wanting on both specimens, but the umbonal region was evidently deep or tumid; the shell appears to have been extremely thin or fragile.

Lima cottaldina, D'Orb., from the Gault (Aptian) resembles our shell in many respects, but the intercostal spaces in our shell are wider and decussated instead of being nodular; in shape, tumidity of the umbo, and probable smallness of the hinge line and wings, they are closely allied.

One of the specimens is preserved in a light coloured phosphate, the other in a clayey marl, but both are from the Cambridge Greensand or Phosphatic bed.

Locality Cambridge (Cambridge Greensand).

Collection, Woodwardian Museum.

Avicula filuta, Etheridge. Pl. 2, Figs. 3, 3a.

Shell small, equivalve, inæquilateral, hinge line straight, as long as the shell, ventral margin nearly circular, anterior side rounded, ventral valve deep, especially so at the umbonal region; valves marked by faint thread-like radiating slightly wavy lines, 14–16 in number, ranging from the umbo to the ventral margin, here and there these lines bifurcate, shell structure thin, dense, and glazed.

In many respects this shell resembles the sub-genus *Monotis*, Bronn, especially in its rounded anterior side. *Pseudomonotis* (*Oxytoma*) *semiglobosa* of the Arrioloow group,† resembles our shell both in the filiform striæ and lines of growth which are densely arranged, as well as in general habit. The largest example measures $\frac{7}{8}$ of an inch in length by $\frac{6}{8}$ in depth.

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* Pal. Franc., Terr. crét., vol. 3, p. 537, t. 416, p. 5.

† Pal. Indica, vol. 3, p. 402, Pl. 26, Fig. 1.

The genus *Petèria*, Scopoli, may receive this shell, but want of internal characters prevents our definitely determining this alliance.
Locality, Burwell (Totternhoe Stone).
Collection, Woodwardian Museum, Cambridge.

Avicula dubia, Etheridge. Pl. 2, Figs. 4, 4a.

Shell small, inæquilateral, ventral margin round, hinge line straight, longer than width of the shell. Posterior side expanded, anterior side short, byssal notch well defined.

The external portion of this shell is not seen, therefore unknown to me, although placed upon the same tablet in the Woodwardian collection, with *Avicula filata*, it certainly does not belong to that species. The shell is thicker, stronger, and rounder in form than *A. filata*, again no byssal sinus is seen under the anterior part of the hinge line of *Av. filata* and the latter species possesses a larger wing.

Small as this shell is, there is no doubt it is mature, and not a young form. We have only two specimens, both interiors, one may be the lower and the other the upper valve; they appear to belong to the same species.
Locality, Burwell (Totternhoe Stone.)
Collection, Woodwardian Museum, Cambridge.

Spondylus æquicostatus, Etheridge. Pl. 2, Fig. 5.

Shell very inæquilateral, rhomboidal, ventricose, densely costated, the costæ being all equal in size and gently waved, and about 80 in number. The interspaces are shallow, and about the same width as the costæ, especially near the centre of the valves. Umbo obtuse, hinge line straight; area not seen in our specimens, lines of growth irregular and general surface of the shell wavy or undulating. The hinge area *appears* to have been small, about one-third the length of the shell.

One of the specimens in the Woodwardian Collection shows along the ventral margin of the attached valve a nearly vertical thickening at an angle of 60°, which does not occur in the same valve of the other specimens; but for the peculiar habit of the shell, it might be taken for Lima or Hinnites; it is, however, too inæquilateral for the latter genus, and the want of symmetry removes it from Lima. The want of hinge line adds to the difficulty of determination.
Locality, Cherry Hinton (in the zone of *Holaster sub-globosus* above Totternhoe beds and below the zone of *Belemnites plenus* or the Melbourn Rock).
Collection, Woodwardian Museum.

Anomia papyracea, D'Orb., var. *Burwellensis*, Etheridge, Pl. 3, Figs. 3, 4.

Shell thin, inæquivalve, inæquilateral, orbicular or rhomboidal, smooth or nearly so, umbones rather acute and slightly rugose. Ventral margin rounded, lines of growth on some specimens conspicuous. On one of the specimens figured, Fig. 4, there are peculiar vertical lines running from the umbonal region to the edge of the shell.

The above shell figured by D'ORBIGNY* closely resembles the Burwell form in the Woodwardian Collection; to so variable a shell I am compelled to give a distinguishing varietal name.

No Anomia is mentioned or described from any part of the Chalk of Britain, one species occurs in the Cambridge Greensand (*Anomia transversa*, Seeley), and four species are known in the Neocomian, which completes the known species from the British cretaceous rocks. Their non-recognition from the true Chalk is singular, and shows extreme rarity, as few formations have been more extensively worked, or their fossil contents more carefully examined than the Upper and Lower Chalk of England.

Our variety of D'ORBIGNY'S *Anomia papyracea* (*A. Burwellensis*) is, as usual with species, and specimens in this genus, very variable in shape, and certain markings on the shell may be due to attachment to other forms, therefore,

* Pal. Franc., Terr. crét., vol. 3. p. 755, t. 489, f. 7–10.

as a rule, no value can be attached to them. We figure this species from the Woodwardian Collection, Cambridge, as it seems abundant in the Totternhoe Stone at Burwell, and as being the only form known to us from the Chalk. Neither NILLSON or RÖMER name or figure any form of Anomia; REUSS, in his Verstein. der Böhm Kreide, names and figures four species, but neither are near our variety. The Southern Indian cretaceous deposits have yielded but one species of Anomia (*A. variata*, Stol.); America, only 10; and all Europe not more than 20 species.

Locality, Burwell (Totternhoe Stone).

Collection, Woodwardian Museum, Cambridge.

Ostrea acutirostris, Nilsson, Petref. Succ. p. 31, t. 6, f. 6. Pl. 3, Figs. 5, 6.

Shell elongated, slightly curved, umbo acute, muscular scars elongated, ova and large, a single elevated transverse ridge or triangular space occupies the small area under the acute umbo, which is transversely striated, two lateral projections or blunt teeth occur on both sides, and immediately under the area, ligamental ridge minutely crenulated.

We have not the exterior of this shell so as to enable us to state with NILSSON, "*loc. cit.*," that the "lower valve is radiately plicated and rugose, and "that the upper or superior valve is also convex and rugose;" nevertheless, this shell can be no other than NILSSON's *Ost. acutirostris*. The figure given by D'ORBIGNY* agrees tolerably well with NILSSON's description, both as to the convexity of the upper valve and rugosity in both. We have not met with any published notice of this shell in Britain, although it is said to have been found in the Upper Chalk of Dover and Brighton. NILSSON, D'ORBIGNY, and GOLDFUSS figure the species, but they all more or less vary in their delineations in the form of the shell, especially so in the umbonal region. The two Cambridge specimens, which appear to be the attached valves, are the only specimens known to me from that or any other area; I therefore figure them in order to draw attention to their probable occurrence. I feel by no means certain that it is the shell, but they greatly resemble the form figured by NILSSON and D'ORBIGNY.

Locality, Burwell (Totternhoe Stone).

Collection, Woodwardian Museum, Cambridge.

Ostrea curvirostris, Nillson, var. *inflexa*, Etheridge, Pl. 3, Figs. 7, 8.

Shell elongated, gently arcuated or curved, right valve slightly ventricose, thick or deep near the umbonal region; ligamental area in right valve, toothed or crenulated for a short distance from the umbo; shell moderately thick; the right or upper valve is haliotoid in form, indeed strongly resembles the upper valve of *Exogyra haliotoidea*, Sow.; the markings that pass or occur across the shell in the Cambridge Collection may be due to attachment or growth upon some other form as they are not distinguishable upon all the specimens on the tablet.

Although our specimens do not quite agree with NILSSON's figures, yet making allowance for the variation of growth in species of this genus, it would be unwise to make the Cambridge specimens new species, probably both the true *Ost. curvirostris* and *Ost. acutirostris* occur in the Burwell Lower Chalk of the Cambridge area. The Cambridge shells are not quite so elongated or acutely pointed as the form figured and described by NILSSON† or D'ORBIGNY.‡ There is, however, sufficient variation and difference to enable me to give it the varietal name and also figure two specimens. Again, the Burwell species are more tumid than NILSSON's, his form and figure being more acute and longer; the figure given by GOLDFUSS§ is also more curved and acute; the umbo not being so involute as in the Cambridge shell. Messrs. PICTET and CAMPIECHE|| figure D'ORBIGNY's species *O. Rauliniana*,

* Pal. Franc., Terr. crét., t. 481, f. 1-3.
† Petref. Suec., p. 30, t. 6, f. 5.
‡ Pal. Franc., Terr. crét., t. 488, f. 9-11.
§ Petref. Germ., vol. 2, p. 24, t. 82, f. 2.
|| Desc. Foss Terr. crét., St. Croix, part 5, p. 307, t. 193, f. 15-16.

which very closely resembles our shell, more so, indeed, than the French as figured on Tab. 471, Figs. 1–3, of the Paléontologie Française; to all these I draw attention on account of the uncertainty of determination from few specimens.

Localities, Burwell, Orwell, and Haslingfield (Totternhoe Stone).

Collection, Woodwardian Museum, Cambridge.

BRACHIOPODA.

Rhynchonella Reedensis, Etheridge. Pl. 3, Fig. 12.

Shell oval, width equal to length, obtusely rounded, ventral valve flatter than the dorsal, and thickened near the umbo, having also a broad but shallow sinus, beak very small, acute, not incurved, dorsal valve more gibbous than the ventra valve, foramen minute, round, surrounded by the small deltidium, beak ridges sub-acute, almost obsolete, hinge line wavy, or gently undulating ribs or costæ about 20, 7 to 8 on the mesial fold, all equal sized or equally developed along the frontal margin, apparently not divided or split as in *R. Woodwardi*.

This shell very closely resembles *R. Woodwardi*, Davidson,* but not the *Tereb gallina*, Woodward,† which shell is much wider, more numerously ribbed, and the beak much more acute than in our species. The extreme smallness and acuteness of the beak and size of foramen serves also to distinguish it from the above species and also from *R. Cuvieri*.

Stratigraphically this is an important shell on account of its always occurring in the Chalk Rock and in the few feet below. At the Reed and Barley Chalk pits it is a characteristic shell, distinctly marking or determining the Chalk Rock as a zonal horizon. This fact alone induces me to figure this form regardless of its close affinity with *R. Woodwardi*, Dav.

Localities, Reed and north of Barkaway, and near Barley (Chalk Rock).

Collection, Museum of Practical Geology.

Terebratulina gracilis, Schloth., var. *lata*, Etheridge. Pl. 3, Fig. 14.

Shell nearly orbicular, expanded, or broadly triangular, equal in width and length, ventral or dental valve convex, the smaller or dorsal valve nearly flat; the ribs or costæ in both valves slightly ornamented by inbricating delicate lines of growth, which arch over the ribs, giving them the appearance of being nodulated; alternating or intermittent ribs occur with the last growth of the shell, there are about 22 chief or primary, and 8 smaller or shorter. This variety appears to be confined to the Middle Chalk, and is particularly abundant in the middle zone of this division. That considerable difference and variation occurs amongst the species of this genus there can be no doubt, both as regards form and external characters, and this zoological difference has important stratigraphical value also, as this and other varieties in species of the same genus serves to clearly determine zonal horizons over large areas.

It is difficult to distinguish this variety from the figure of *T. gracilis* given by Mr. DAVIDSON,‡ except that the number of ribs are greater in his figures, and our specimens are flatter and wider.

We have a *globose* variety in the same beds, and the variety *lata* is the *T. gracilis* of that zone, or the variety characteristic of it.

Localities, Middle Chalk, *passim*.

Collection, Museum of Practical Geology.

Terebratulina gracilis, Schloth. var *nodulosa*, Etheridge. Pl. 3, Fig. 13.

Shell longer than wide. Beak area in ventral valve acute. Primary costæ, 10 to 12 in number, densely and closely nodulated; secondary costæ, 6 to 8, which are about half as long as the primary.

This nodulose variety contains fewer ribs, which are also more densely nodulated than in the typical *T. gracilis* as figured by Mr. DAVIDSON.§ Again, in our specimens the dorsal valve is convex or globose, instead of flat as in Mr. DAVIDSON's figures.

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* Brit. Cret. Brach., Pal. Soc., p. 77, 10, figs. 45–46.

† Geology of Norfolk, t. 6, f. 12.

‡ Cretaceous Brachiopoda, Pal. Soc., t. 2, f. 13–14.

§ Cretaceous Brachiopoda, Pal. Soc., p. 38, t. 2, f. 13–15, 1852–55.

This variety is confined to the Totternhoe Stone and part of the Grey Chalk immediately above or overlying it.

Localities, Cherry Hinton and Burwell (Totternhoe Stone).

Collection, Museum of Practical Geology.

Terebratulina striata, var., *triangularis*, Ether. Pl. 3, Fig. 15.

Shell triangular in form, longer than wide. Beak tapering or acutely rounded, hinge line straight. Foramen large, deltidium small. Beak ridge indistinct, valves equally ventricose or convex, frontal margin broadly rounded, costæ about 24, nearly half of which (or the secondary costæ) are half the length of the primary; many of the chief ribs are split or divided on reaching the ventral margin, lines of growth well defined.

This shell is very abundant in the Cambridge Greensand, and has hitherto been considered as *T. gracilis*, var. *rigida*, of Sow. (M.C., vol. 6, p. 69, t. 536, f. 2), also Davidson (Brit. Cret. Brach., Pal. Soc., p. 38, t. 2, ff. 13–15). But I have little doubt that it is rather a variety of *T. striata*, Wahl, and the triangular form of this shell has suggested the varietal name.

Localities, near Cambridge, *passim* (Cambridge Greensand).

Collection, Woodwardian Museum, and Museum of Practical Geology.

APPENDIX B.

LIST OF GAULT FOSSILS (*remaniés*) FOUND IN THE "CAMBRIDGE GREENSAND."

By A. J. JUKES-BROWNE.

This list is based upon that given in *Quart. Journ. Geol. Soc.*, vol. xxxi. p. 305, supplemented by that in vol. xxxiii. p. 504, and by still later additions and corrections.

Many species are included which have not yet been found elsewhere, because their mineral condition is identical with that of the Gault fossils, and it is thought that they have been derived from the same beds as their companions.

The fish remains have been identified by Mr. E. T. Newton (see Catalogue of Cretaceous Fossils in the Museum of Practical Geology, 1878).

The list of Reptiles includes only those species which have been fully described, the names affixed to many specimens in the Woodwardian Museum by Prof. SEELEY not being inserted.

In the first column opposite the names, those species are indicated which occur in the English Gault; the second column contains those also found in the Gault Supérieur of France and Switzerland; Dr. BARROIS' recent memoir* has enabled me to make some fresh insertions in this column.

The total number of named species of Invertebrata in this list is 215; of these 122 are known also in the Gault of England, and 98 are found in the Gault Supérieur of France and Switzerland. The Vertebrata are 48 in number.

——	English Gault.	Gault Supérieur.
AVES.		
Enaliornis Barretti, *Seeley*.		
„ Sedgwickii, *Seeley*.		
REPTILIA.		
Chelone (Rhinochelys) pulchriceps, *Owen*.		
„ „ (several species) - - - -	×	
Crocodilus Cantabrigiensis, *Seeley*.		
„ Icenicus, *Seeley*.		
Ichthyosaurus campylodon, *Carter* - - -	×	
„ Walkeri, *Seeley* - - - -	?	
Ornithocheirus ? Cuvieri, *Bowerbank*.		
„ denticulatus, *Seeley*.		
„ machærorhynchus, *Seeley*.		
„ Sedgwickii, *Owen*.		
„ simus, *Owen*.		
„ Woodwardii, *Owen*.		
Plesiosaurus ? Bernardi, *Owen*.		
„ constrictus, *Owen*.		
„ latispinus, *Owen*.		
„ Neocomiensis, *Camp*.		
„ planus, *Owen* - - -	?	
Polyptychodon interruptus, *Owen* - - - -	×	×
? Synyonosaurus macrocercus, *Seeley*.		

* *Ann. Soc. Geol. Nord.*, vol. v. p. 227.

——	English Gault.	Gault Supérieur.
Pisces.		
Cimolichthys (Saurocephalus) striatus, *Ag.*		
Drepanophorus canaliculatus, *Eg.*		
Edaphodon crassus, *Newton.*		
„ laminosus, *Newton*	×	
„ Reedii, *Newton.*		
„ Sedgwickii, *Ag.*		
? Enchodus halocyon, *Ag.*	×	
Hybodus sp.	×	
Ischyodus brevirostris, *Ag.*	×	
„ latus, *Newton.*		
„ planus ?, *Newton.*		
Lamna acuminata, *Ag*	...	×
„ gracilis, *Pictet & Camp.*	×	×
„ plicatella, *Reuss.*		
„ subulata, *Ag.*	×	×
Lepidotus sp.		
Otodus appendiculatus, *Ag.*	×	×
Oxyrhina macrorhiza, *Pictet & Camp.*	...	×
? „ Mantelli, *Ag.*		
Pachyrhizodus glyphodus ?, *Blake*	×	
Pisodus sp.	×	
Plethodus expansus, *Dixon.*		
Portheus Gaultinus, *Newton*	×	
Protosphyræna ferox, *Leidy.* (Saurocephalus lanciformis, *Ag.*, not *Harlan*)	×	
Ptychodus spectabilis, *Ag.*		
Pycnodus cretaceus, *Ag.*		
„ parallelus ?, *Eg.*		
Sphenonchus sp.		
Cephalopoda.		
Ammonites auritus, *Sby.*	×	×
„ „ var. Renauxianus, *D'Orb.*	...	×
„ „ var. Salteri, *Sharpe.*		
„ cœlonotus, *Seeley*	×	
„ „ var. valbonnensis, *Heb.*	...	?
„ glossonotus, *Seeley.*		
„ latidorsatus, *Mich.*	×	× ?
„ planulatus, *Sby.*	×	×
„ „ var. Mayorianus, *D'Orb.*	×	×
„ Raulinianus, *D'Orb.*	×	×
„ „ var. tetragonus, *Seeley.*		
„ rhamnonotus, *Seeley* (= Gardonicus, *Heb.*	...	?
„ „ var. sexangulatus, *Seeley.*		
„ rostratus, *Sby.*	×	×
„ „ var. ? candollianus, *D'Orb.*	×	×
„ „ var. inflatus, *Sby.*	×	×
„ splendens, *Sby.*	×	×
„ „ var. cratus, *Seeley*	×	
„ „ var. leptus, *Seeley.*		
„ Studeri, *Pictet & Camp.*	×	×
„ Timotheanus, *Mayor.*	...	×
„ Vraconnensis, *Pictet*	...	×
„ Woodwardii, *Seeley.*		
Ancyloceras tuberculatum, *Sby.*	×	
Anisoceras armatum, *Sby.*	×	×
„ Saussureanum, *Pictet*	×	×
Baculites baculoides, *D'Orb.*	...	×
„ Gaudini, *Pict. & Camp.*	×	×
Belemnites minimus, *Lister*	×	×
„ ultimus, *D'Orb.*	×	×

—	English Gault.	Gault Supérieur.
Cephalopoda—*cont.*		
Conoteuthis, sp.		
Hamites intermedius, *Sby.*	×	×
„ virgulatus, *Pictet*	×	×
Helicoceras quadri-tuberculatum (?).		
„ Robertianum, *D'Orb.*	×	×
Nautilus albensis, *D'Orb.*	×	×
„ arcuatus, *Desh.*	×	?
„ clementinus, *D'Orb.*	×	×
„ inæqualis, *Sby.*	×	
„ largilliertianus, *D'Orb.*	...	×
„ Montmollini ?, *Pictet*	×	
Scaphites Hugardianus, *D'Orb.*	×	×
„ „ var. Meriani, *Pict. & Camp.*	...	×
„ „ var. simplex, *Jukes-Browne*	×	
Turrilites Bergeri, *Brongn.*	×	×
„ elegans ?, *D'Orb.*	×	
„ emericianus ?, *D'Orb.*		
„ Hugardianus, *D'Orb.*	×	×
„ nobilis, *Jukes-Browne.*		
„ Puzosianus, *D'Orb.*	...	×
„ Wiestii, *Sharpe* (var. Cantabrigiensis).		
Gasteropoda.		
Acmæa tenuicosta ?, *Desh.*	×	
„ „ var. tenuistriata, *Seeley.*		
Aporrhais carinata, *Mant.*	×	×
„ elongata, *Sby.*	×	
„ histochila, *Gard.*		
„ marginata, *Sby.*	×	×
„ Parkinsoni, *Mant.*	×	×
„ retusa, *Sby.*	×	×
„ „ var. globulata, *Seeley.*		
Avellana Hugardianus, *D'Orb.*	×	×
„ incrassata, *Sby.*	×	×
„ ventricosa, *Seeley.*		
Brachystoma angulare, *Seeley*	×	
Buccinum Gaultinum, *D'Orb.*	×	
Cerithium sp.		
Chemnitzia tenuistrata, *Seeley*	?	
Crepidula Cooksoniæ, *Seeley*	...	×
„ Gaultina, *Buv.*	×	×
Dentalium decussatum, *Sby.*	×	×
Funis elongatus, *Seeley.*		
Fusus quinquecostatus, *Seeley.*		
„ Smithii, *Sby.*	×	?
„ tricostatus, *Seeley.*		
Gibbula levistriata, *Seeley.*		
? Hipponyx Dixoni, *Desh.*		
Littorina crebricostata, *Seeley.*		
Natica clementina, *D'Orb.*	×	×
„ Gaultina, *D'Orb.*	×	×
„ levistriata, *Jukes-Browne*	×	
„ Rhodani, *D'Orb.*	...	×
Nerinæa, sp.		
Nerita nodulosa, *Jukes-Browne.*		
„ (Neritopsis) scalaris, *Seeley.*		
Pleurotomaria Allobrogensis, *Pict. & Roux.*	...	×
„ Gibbsii, *Sby.*	×	×
„ Iteriana ?, *Pict. & Camp.*	?	×
„ Jukesii, *Seeley.*		
„ La Harpii, *Pict. & Camp.*	...	×

———	English Gault.	Gault Supérieur.
GASTEROPODA—*cont.*		
Pleurotomaria lima, *D'Orb.*	×	?
„ regina, *Pict. & Roux.*	...	×
„ Rhodani, *D'Orb.*	×	×
„ Rouxii, *D'Orb.*	×	×
„ semiconcava, *Seeley.*		
„ Vraconensis, *Pict. & Camp.*	...	×
Solarium Carteri, *Seeley.*		
„ dentatum, *Desh.*	×	×
„ granosum, *D'Orb.*	×	
„ ornatum, *Sby.*	×	×
„ planum, *Seeley.*		
„ Rochatianum, *Pict. & Roux.*	...	×
„ Sedgwickii, *Seeley.*		
Stomatodon politus, *Seeley.*		
Tornatella pyrostoma, *Seeley.*		
Trochus cancellatus, *Seeley* (indecisus, *D'Orb.*)	×	?
Turbo Pictetianus, *D'Orb.* (nodosa, *Seeley*)	×	×
LAMELLIBRANCHIATA.		
Arca Hugardiana, *D'Orb.*	×	×
„ nana, *D'Orb.*	×	
Avicula gryphæoides, *Sby.*	×	×
Cardita tenuicosta ?, *Sby.*	×	×
Cucullæa glabra, *Park.*	×	
Exogyra conica, *Sby.*	×	×
„ „ var. plicata, *Sby.*	×	
„ Rauliniana, *D'Orb.*	×	×
Fimbria Gaultina, *Pict.*	...	×
Gervillia solenoides, *Defr.*	×	
Inoceramus concentricus, *Park.*	×	×
„ sulcatus ?, *Park.*	×	×
Isoarca Agassizii, *Pict. & Roux.*	...	×
Leda solea, *D'Orb.*	×	
Lima elongata, *Sby.*	×	×
„ globosa, *Sby.*	×	
„ interlineata, *Jukes-Browne.*		
„ Rauliniana, *D'Orb.*	×	×
Lucina tenera, *Sby.*	×	
Nucula Albensis, *D'Orb.*	×	
„ bivirgata, *Sby.*	×	×
„ ovata, *Mant.*	×	×
„ rhomboidea, *Seeley.*		
„ subelliptica, *Seeley.*		
„ vibrayeana, *D'Orb.*	×	
Ostrea frons, *Park.*	×	×
„ vesicularis, *Sby.*	×	×
Pecten aptiensis, *D'Orb.*, var. Barretti, *Seeley*	...	?
„ orbicularis, *Sby.*	×	×
„ Raulinianus, *D'Orb.*	×	×
„ subacutus ?, *D'Orb.*		
„ (Neithea) quadricostata, *Sby.*	×	×
„ („) quinquecostata, *Sby.*	×	×
„ (Hinnites) pectinatus, *Seeley, M. S.*		
„ („) Studeri, *Pict & Roux.*	×	×
„ („) trilinearis, *Seeley.*		
Perna lanceolata, *Geintz*	×	
„ oblonga, *Seeley.*		
„ Rauliniana, *D'Orb.*	×	×
„ semie liptica, *Seeley.*		
„ subspathulata, *Reuss*	×	

	English Gault.	Gault Supérieur.
Lamellibranchiata—*cont.*		
Pholadomya decussata, *Sby.*, var. triangularis, *Seeley*	?	
Plicatula pectinoides, *Sby.*	×	×
„ sigillina, *Woodward*	×	×
Spondylus gibbosus, *D'Orb.*	×	×
Tellina phaseolina, *Pict. & Camp.*	×	×
Teredo sp.		
Brachiopoda.		
Kingena lima, *Defr.*	×	×
Rhynchonella dimidiata, *Sby.*	...	×
„ „ var. convexa.		
„ sulcata, *Lam.*	?	×
Terebratula biplicata, *Sby.*, var. Dutempleana, *D'Orb.*	×	×
„ „ var. obtusa, *Sby.*	×	×
Crustacea.		
Cyphonotus incertus, *Bell.*		
Diaulax Carteriana, *Bell*	×	
Etyus Martini, *Mant.*	×	
„ similis, *Bell.*		
Eucorystes Carteri, *McCoy.*		
Glyphæa Carteri, *Bell.*		
„ cretacea, *McCoy*	×	
Hemioon Cunningtoni, *Bell.*		
Homolopsis Edwardsii, *Bell*	×	
Hoploparia scabra, *Bell*	×	
„ sulcirostris, *Bell*	×	
Necrocarcinus Beechii, *Deslong.*	×	
„ tricarinatus, *Bell*	×	
„ Woodwardii, *Bell*	×	
Palæocorystes Stokesii, *Mant.*	×	
Phlyctisoma granulatum, *Bell.*		
„ tuberculatum, *Bell.*		
Scillaridea cretacea, *Seeley, M. S.*		
Squilla McCoyi, *Seeley, M. S.*		
Xanthosia granulosa, *McCoy.*		
——		
Serpula antiquata, *Sby.*	?	×
Serpula plexus, *Sby.*	×	
Echinodermata.		
Cidaris Gaultina, *Forbes*	×	
Galerites castaneus ?, *Brongn.*		
Hemiaster M'Coyi, *Seeley*	×	
Hemipneustes sp.		
Holaster lævis, *Deluc.*	...	×
Pentacrinus Fittoni ?, *Aust.*	×	
Pseudodiadema Barretti, *Woodwd.*		
„ Carteri, *Woodwd.*		
„ fungoideum, *Seeley.*		
„ intertuberculatum, *Seeley.*		
„ inversum, *Seeley.*		
„ ornatum, *Goldf.*		
„ scriptum, *Seeley.*		
„ variolare, *Brong.*		
Salenia sp.		

—	English Gault.	Gault Supérieur.
Actinozoa.		
Isastræa sp. - - - - - -	×	
Trochocyathus angulatus, *Dunc.* - - - -	×	×
„ conulus, *Edw.* - - - -	×	×
„ Harveyanus, *Edw.* - - -	×	×
Spongidæ.		
Acanthophora Hartogii, *Sollas.*		
Bonneyia bacilliformis, *Sollas* - - - -	×	?
(and four other species, *Sollas*).		
Brachiolites tubulatus, *Smith.*		
Cephalites Benettiæ, *Mant.*		
„ capitatus, *Smith.*		
„ compressus, *Smith.*		
„ guttatus, *Smith* - - - -	?	
Eubrachus clausus, *Sollas.*		
Hylospongia Brunii, *Sollas* - - - -	×	
(and two other species, *Sollas*).		
Pharetrospongia Strahani, *Sollas.*		
Polyacantha Etheredgii, *Sollas* - - - -	×	
Retia costata, *Sollas* - - - - -	...	×
„ simplex, *Sollas* - - - - -	×	
Rhabdospongia communis, *Sollas* - - - -	×	
Ventriculites cavatus, *Smith.*		
„ mammillaris, *Smith.*		
„ quincuncialis, *Smith* - - -	×	
„ texturatus, *Goldf.*		
—		
Parkeria compressa, *Carter.*		
? „ nodosa, *Carter.*		
? „ sphærica, *Carter.*		

APPENDIX C.

WELL SECTIONS.

[Where not otherwise stated these are in Sheet 51, S.W.]

CAMBRIDGESHIRE.

1. BABRAHAM. Worsted Lodge. Cottages.

Communicated by Mr. H. Tomlison, C.E.

128 feet above Ordnance datum.
Water stands 58½ feet from surface.

Chalk - - - - - - 65 feet.

2. BALSHAM. Parish well.

Communicated by Mr. H. Tomlison, C.E.

387 feet above Ordnance datum.
Water stands 175 feet from surface.

Boulder Clay and Chalk - - - - 275 feet.

3. BALSHAM (2 miles N.W. of) Dotterel Hall.

Sunk 162 feet, the rest bored.

White Chalk with Greyish Chalk at bottom - 309 feet.

4, 5. BALSHAM (2 miles W. of) Gunner's Hall.

295 feet above Ordnance datum.
At the Farm, water stands 219 feet from surface.

Boulder Clay and Chalk - - - 229 feet.

At the Cottages, at a lower level:—

Chalk - - - - - - 175 feet.

6. BARNWELL. The large Brickyard.

Communicated by Mr. Lee.
Shaft 20 feet, the rest bored.

	Feet.
[Chalk Marl] Soil and white clay - - -	10
[Gault] Blue clay - - - - -	150

7. BARRINGTON.

Communicated by Mr. N. W. Johnson.

	Feet.
Gault - - - - - - about	150
"Rock" and sand - - - - -	5–10
	155 to 160

8. BARRINGTON. Coprolite works, west of Church.

Four or five wells, varying from 70 to 125 feet in depth. In one the water overflows at the surface, in others it stands at varying depths down to 25 feet.

9. BARRINGTON. Coprolite-works, three-quarters of a mile E. by N. of the Church.

Water overflows.

	Feet.
Chalk Marl	15
Gault and Lower Greensand	185

10. BARTON. A quarter of a mile N. of the Church.

Communicated by Mr. N. W. Johnson.
Shaft, 55 feet, the rest bored.
Water rises to within 38 feet of the surface.

	Feet.
Chalk Marl	22
Gault	113
Rock	9
	144

11. BOTTISHAM-LOAD.

Communicated by Mr. Flavell.

	Feet.
Earth and white clay [Chalk Marl]	21
Blue clay [Gault], rocks and sand	130
	151

12. BOTTISHAM FEN.

Communicated by Mr. Flavell.

	Feet.
Black earth	4
[Chalk Marl], white clay	8
[Gault and ? Lower Greensand], blue clay, rocks and sand	130
	142

Another version of this well shows:

	Feet.
Dug down to coprolites	10
Bored through Gault and Greensand	120
	130

13. BOTTISHAM SLUICE.

Communicated by Mr. Flavell.

	Feet.
Black earth	5
Blue clay [Gault]	120
Rocks and sand	—

14. BOURN, near (3 miles S.S.W of Elsworth).

Prof. H. G. SEELEY. Ann. and Mag. Nat. Hist. ser. 3, vol. x. p. 100.

	Feet.
Hard blue clay	84
Alternate bands of stone and sand, with a layer of extremely hard grey-blue rock	14
? Blue clay to bottom of well	52
	150

15. CALDECOTE. Mr. Westrope's.

Sunk 27 feet, the rest bored.
Water stands 17 feet from the surface.

Gault (? and Boulder-clay) - - - - 67 feet.

The bore-hole ends in the top of a hard rock.

16. CAMBRIDGE. Bateman Street. (Mr. Headley's.)

	Feet.
Soil and clunch [Chalk Marl] - - - -	16
[Gault] blue clay to Greensand and water - -	120

Another account of this well gives the thickness of the Gault as 160 feet.

17. CAMBRIDGE. Coprolite Works near the Observatory.

Communicated by the foreman.

	Feet.
Gravel - - - - - -	12
Chalk Marl - - - - - -	12
Gault to rock - - - - - -	120
	144

17*a*. CAMBRIDGE. Cemetery.

Gault to rock - - - - - - 130 feet.

18. CAMBRIDGE. East road and New Town generally, the wells are, as below.

Communicated by Mr. Coulson, Builder.

	Feet.
Gravel - - - - - -	10 to 20
Gault - - - - - about	130
Sand and rocky beds - - - -	5 to 10
	145 to 160

19. CAMBRIDGE. Coldham's Common.

Communicated by Mr. Flavell.

	Feet.
[Chalk Marl] soil and marl - - - - -	27
[Gault] blue clay - - - - -	120
[Lower Greensand], clayey sand and "rock" -	10
	157

20. CAMBRIDGE. Coldhams Common.

Communicated by Mr. Coe.

	Feet.
[Chalk Marl] soil and marl - - - - -	18
[Gault] blue clay - - - - -	107
	125

21. CAMBRIDGE. Coldhams Common. Coprolite works on northern side.

Communicated by the Foreman.

	Feet.
Chalk Marl - - - - - -	10
Blue clay (bored) - - - - -	120
	130

22. CAMBRIDGE. Coldhams Common, N. side.

Communicated by Mr. Lee.

	Feet.
[Chalk Marl] white clay	10
[Gault] blue clay	130
Rock	$\frac{1}{2}$
	$140\frac{1}{2}$

23. CAMBRIDGE. Coldhams Common. Coprolite works, a quarter of a mile S. of.

Communicated by Mr. Coe.

		Feet.
[Chalk Marl] grey and blue marl		23
[Gault]	Blue clay	110
	Dark clayey sand and coprolites	6
[Lower Greensand] hard rock		11
		150

23. CAMBRIDGE. Hills Road (Mr. Thoday's).

Communicated by Mr. Flavell.

	Feet.
[Chalk Marl] soil and clunch	20
[Gault] blue clay	160
Black sand and rock	20
	200

This well is exceptionally deep, and Mr. Thoday states that alternations of hard and soft beds were met with below the Gault. The thickness of the latter is also doubtful.

25. CAMBRIDGE. Railway Station.

Communicated by Mr. Flavell.

Shaft 60 feet, the rest bored.

	Feet.
Gravel and clunch	20
Gault, with coprolites, at 40 feet down	120
Sand, a few feet	—
	140+

26. Another well given as at the railway, probably at Mill Road level-crossing: passed through—

	Feet.
Gravel	6
[Chalk Marl] white clay	20
[Gault and Lower Greensand] blue clay, rocks and sand	130
	156

27. Cherry Hinton. Cambridge Waterworks. Originally 46 feet; deepened in 1875.

Communicated by Mr. H. Tomlison, C.E.

Shaft to the Gault, the rest bored.
Water within a few feet of the surface.

		Feet.
[Chalk Marl, 48 feet.]	Soil and light-coloured marl	6
	Darker clunch	23
	Light-coloured clunch or marl	7
	Greyish chalk	4
	Blue clunch, with coprolite bed at bottom	8
Gault.	Slate-grey clay, with a band of small grey coprolites 33 feet from the bottom	125
[Lower Greensand.]	Brown clayey sand, with ferruginous phosphate nodules at bottom, and a hard rock below	2
	Soft brown sand with water	1
		176

28–30. Cherry Hinton. 1. Cottage opposite the Robin Hood. 2. Bishop's Charity Farm. 3. Hill's Charity Farm.

Communicated by Mr. H. Tomlison, C.E.

——	1.	2.	3.
Height above Ordnance datum	55	167	171
Water level, below surface	37½	126	129
Depth of well in chalk	40	132	132

31. Chesterton.

Communicated by N. W. Johnson.

	Feet.
[Valley Drift] gravel and sand	10
[Gault] blue clay	105
[Lower Greensand] rock and sand	8
	123

32. Conington. (51 N.W.)

Seeley. Ann. and Mag. Nat. Hist. ser. iii. vol. x. p. 103.

	Feet.
Blue clay	100
Hard rock	5
Blue clay	145
To rock, yielding a small supply of *salt* water	250

33. Coton.

Communicated by Mr. Flavell.

	Feet.
[Chalk Marl] soil and white clay	11
[Gault] blue clay	120
Lower Greensand] rocks and sand	—
	131+

34. COTON. Wells at Coprolite works.
Communicated by Mr. N. W. Johnson.

	Feet.
Gault - - - - - -	120 to 130
Rock and sand - - - - - -	8 „ 12

35. COTTENHAM. (51 N.W.)
Communicated by Mr. Flavell.

	Feet.
Black earth - - - - - - -	4
Blue clay, mixed with rock - - - -	200
Rock and sands - - - - - - -	—

36. DRY DRAYTON. Scotland Farm.
Sunk 114 feet, bored 30 feet.
Water, 100 feet from surface.
Boulder Clay and Gault.

The wells in the lower part of this village are 50 feet deep, in the upper part by the rectory, 180 to 190 feet.

37. EVERSDEN. Coprolite Works.
Communicated by Mr. N. W. Johnson.

	Feet.
Gault - - - - - - -	125 to 135
Lower Greensand, rock and sand - - -	10 „ 15
	135 „ 150

38. EVERSDEN. The Quarry.
Water, 64 feet from surface.

Chalk - - - - - - - - 72 Feet.

39. FEN DITTON. Coprolite Works.
Communicated by Mr. N. W. Johnson.

	Feet.
[Chalk Marl] white clay, varies from - -	3 to 30
[Gault] blue clay - - - - - -	108 „ 120
[Lower Greensand] rock and sand, varies from -	9 „ 12

40. FEN DITTON. Plough Inn.

	Feet.
Clunch - - - - - - - -	20
Gault - - - - - - - -	110
Rock and sand - - - - - -	10 or 20

41. FULBOURN. County Asylum.
Communicated by Dr. Bacon (Medical Superintendent).
Shaft throughout, water rises to 56 feet from surface.

	Feet.
Clunch - - - - - - - -	59½

42–44. FULBOURN. 1. Fulbourn Mill, W. of the village. 2. Fulbourn Lodge.
3. Fulbourn Valley Farm.
Communicated by Mr. H. Tomlison, C.E.

——	1.	2.	3.
Height above Ordnance datum - -	110	158	100
Depth of well in chalk - - -	76	117	56
Water level, below surface - - -	74	114	53

45. GIRTON. Inn near the Rectory.

Sunk 33 feet, the rest bored.

	Feet.
Gravelly soil - - - - - -	3
Blue clay [Gault] - - - - - -	50
Clayey sand and greensand - - - -	9
Rock, with water - - - - - -	1
	63

46. HARDWICK. Whitwell Farm.

Communicated by Mr. Flavell.

	Feet.
[Chalk Marl] soil and white clay - - - - -	25
[Gault] blue clay - - - - - -	110
[Lower Greensand] rocks and sand - - - -	—

47. HARLTON. Coprolite works.

Communicated by Mr. N. W. Johnson.

	Feet.
Gault - - - - - - -	125 to 135
Lower Greensand, rock and sand - - -	10 „ 15

48. HASLINGFIELD. Coprolite Works.

Communicated by Mr. N. W. Johnson.

	Feet.
Gault - - - - - - -	135 to 145
Lower Greensand, rock and sands - - -	9 „ 18

48*a*. HASLINGFIELD. Coprolite Works near Cantalupe Farm. Obtained from the foreman.

	Feet.
Clunch [Chalk Marl] - - - - - -	20
Blue Clay to rock [Gault] - - - - -	130
	150

49. HASLINGFIELD. Daintrees Inn.

Sunk 33 feet, the rest bored.

	Feet.
Gault, Blue clay, sandy at bottom - - - -	153
Lower Greensand, sand, &c. - - - - -	20
	173

50. HASLINGFIELD. Near the Church.

Communicated by Mr. Pond.

	Feet.
Clunch with coprolites at bottom - - - - -	14
[Gault] clay with coprolites (and *Ammonites interruptus*) at bottom - - - - - - - -	140
[Lower Greensand] rock and greensand - - - -	3
	157

51. Hatley St. George (52 S.E.)

Communicated by Mr. H. Tomlison, C.E.

Sunk 170 feet, the rest bored.

Water rose within 140 feet of the surface.

	Feet.
Clay with chalk stones [Boulder Clay]	120
Gravel (chalk, flints, and pebbles)	28
Gault (clean blue clay)	22
Greensand	30
	200

52. Histon. Fruit Mills, by the Railway Station.

	Feet.
[Valley Drift] gravelly loam	5
[Gault] blue clay	60
[Lower Greensand] rock and sand	5
	70

53. Horningsey, near Highhall Farm.

Communicated by Mr. R. Piggot (Guilden Morden).

	Feet.
Soil and White Clay [Chalk Marl]	15
Blue clay [Gault]	120
Rock and sand [Lower Greensand]	10
	145

54. Kingston. Parish well.

Sunk 89 feet, the rest bored.

Water within 65 feet of the surface.

	Feet.
Gault (and Lower Greensand?)	189

55. Lolworth. Cottage, a mile east of village.

Sunk 35 feet, the rest bored.

No supply, but bore fills in at the bottom when left for a few hours.

Dark [Kimeridge] clay, with bed of rock 30 feet from surface, and at every few feet below - - - - - - - - 135 feet.

56. Madingley.

Communicated by Mr. Flavell.

	Feet.
Soil	3
[Chalk Marl] white clay, with coprolites at bottom	14
[Gault and Lower Greensand] blue clay, rocks and sand	140
	157

57. Madingley Road.

Communicated by Mr. Flavell.

	Feet.
Soil and gravel	7
[Chalk Marl] white clay, with coprolites at bottom	6
[Gault] blue clay	120
[Lower Greensand] rocks and sand	—

58. MELDRETH. By the Church.

Water overflows.

		Feet.
Chalk and Gault - - - -	said to be	300

58*a*. MELDRETH, Railway Station.

Communicated by Mr. F. J. Carver (Whaddon).

Water overflows.

	Feet.
[Chalk Marl] White clay, to coprolites - - -	60
[Gault] Blue clay - - - - - - -	240
[Lower Greensand] Rock - - - - about	5
	305

58*b*. MELDRETH, about a mile N.W. of the Railway Station.

Communicated by Mr. F. J. Carver (Whaddon).

	Feet.
[Chalk Marl] white clay - - - - - -	30
Gault - - - - - - - -	210
[Lower Greensand] rock - - - - - -	8
	248

59. ORWELL. Coprolite works, S.E. of.

Water, 20 feet from surface.

	Feet.
Clunch and Gault - - - - - - -	180

60. OVER. (51 N.W.)

Communicated by Mr. Flavell. No water.

	Feet.
Black earth and gravel - - - - - -	15
Blue [Oxford] clay, with chalk-stone and black rocks -	200
	215

60*a*. PAMPISFORD. Mr. C. Scruby's Brewery.

Sunk and communicated by Mr. J. Ingold.

Water-level 6 feet down, sustained pumping of from 40 to 50 gallons a minute. [Supply probably derived from the Totternhoe Stone.]

		Feet.
Garden mould	- - - - - - -	3
[Middle and Lower Chalk].	Soft white chalk - - - - - -	7
	Hard white chalk - - - - -	16
	" " with soft layers - -	5
	Hard chalk - - - - - - -	13
	Soft grey chalk, with hard piece of chalk at bottom	69
	Very soft chalk - - - - - -	5
	Soft chalk, with hard piece at bottom - -	1
	Soft chalk - - - - - -	6½
		125½

61. SAWSTON. Borough Mills.

The left hand column of figures from particulars and specimens preserved at the Mills. The right hand column communicated by Mr. G. Ingold.

The water comes in from upper part of the Lower Greensand, and rises to 14 feet below the surface, at about 15 gallons a minute. The water is impregnated with salt.

	Feet.	Feet.
Made ground	—	12
Chalk, at 47 feet a bed of flints with much water	145	150
Gault	167	150
Lower Greensand	65	65
? Kimeridge Clay	—	—
	377	377

62. SHELFORD. Mills by Railway Station.

	Feet.
Coarse gravel	10
Clunch, with coprolite-bed at bottom	90
Blue clay	170
Soft bluish earth (" bear's muck ")	2
Brown quick-sand	6
Dark grey ironstone rock	2
	280

63. SHELFORD. Heath Farm.

156 feet above Ordnance datum.

Communicated by Mr. H. Tomlison, C.E.

Water stands 96 feet from surface.

	Feet.
Chalk	102

64. SHELFORD. Lime Kilns, by Little Hill Inn.

119 feet above Ordnance datum.

Communicated by Mr. H. Tomlison, C.E.

Water stands 71 feet from surface.

	Feet.
Chalk	75

65. SHELFORD. Red Cross.

69 feet above Ordnance datum.

Communicated by Mr. H. Tomlison, C.E.

Water stands 25½ feet from surface.

	Feet.
Chalk	32

66. STAPLEFORD. Windmill.

About 120 feet above Ordnance datum.

Water stands 53 feet from surface.

	Feet.
Chalk	63

67. STREATHAM FEN. Dimmock's Cote (51 N.W.)
Communicated by Mr. Flavell.

	Feet.
Black earth - - - - - -	3
Peat - - - - - - -	18
Blue [Kimmeridge] clay - - - - - -	110
Rock and sand - - - - - - -	10
	141

68. STREATHAM FEN. Mr. Feust's Farm (51 N.W.)
Communicated by Mr. Flavell.

	Feet.
Sand and gravel - - - - - - -	12
Blue clay - - - - - - - -	18
Rock and black sand - - - - - -	—

69. SWAFFHAM BULBECK, Longmeadow.
Communicated by Mr. Isaacson.

	Feet.
[Chalk Marl] clunch, with coprolites at bottom - -	42
[Gault] Clay - - - - - -	112
[Lower Greensand] rock and greenish sand, with small pebbles of quartz - - - - - -	15
	169

69a. SWAFFHAM BULBECK, Longmeadow Farm. (North of.)

	Feet.
[Chalk Marl] soil and chalk - - - -	15
[Gault] clay - - - - - - nearly	120
[Lower Greensand] rock and greensand - - about	30
	165

69b. SWAFFHAM (PRIOR?).
Communicated by Mr. Flavell.

	Feet.
[Chalk Marl] soil and white clay - - - - -	83
[Gault and Lower Greensand] blue clay, rock and sands-	120
	203

70. TRUMPINGTON. Mr. Sayle's.
Communicated by Mr. Thoday.

	Feet.
Clunch, with coprolites at bottom - - -	35
[Gault] blue clay - - - - - - -	140
[Lower Greensand] rock and sand - - -	20
	195

71. TRUMPINGTON. Mr. Whitmore's.

	Feet.
Soil and clunch, with coprolites at bottom - -	36
[Gault] blue clay with vein of large coprolites 55 feet from the bottom - - - - - -	136
[Lower Greensand] greensand and water - -	3
	175

72, 72*a*, *b*. Vandlebury. 1. Duke of Leeds' garden. 2. Lodge half a mile E. of. 3. Cot Farm, a mile to S.E.
Communicated by Mr. H. Tomlison, C.E.

—	1.	2.	3.
Height above Ordnance datum - - - -	247	147	113
Depth of well in Chalk - - - - -	206	97	60
Water level from surface - - -	199	91	54

73. Waterbeach.
Communicated by Mr. Flavell.

	Feet.
Black earth - - - - - - -	4
Blue clay [Gault] to rock and sand - - -	120?

74. Waterbeach Fen. Chitering Hill? (51 N.W.)
Communicated by Mr. Flavell.

	Feet.
Black earth - - - - - - -	4
Gravel - - - - - - - -	1
[Gault] blue clay - - - - - - -	40
[Lower Greensand] rock and sand - - -	6
	51

75. Wendy. Coprolite Works S.E. of.
Water overflows.

	Feet.
[Gault] dark clay - - - - - - -	115
[Lower Greensand] { Sand - - - -	3
[Lower Greensand] { Rock - - - -	2
	120

76. Whaddon. Coprolite Works.
Communicated by Mr. F. J. Carver (Whaddon).

	Feet.
Chalk Marl to coprolites - - - - -	5 to 30
Gault clay - - - - - - -	150 to 175
Rock [Lower Greensand] - - - -	5 to 10
	160 to 215

77. Whaddon. Coprolite Works near King's Bridge, one mile N.E. of.
Communicated by Mr. H. Tomlison, C.E.

	Feet.
Chalk Marl - - - - - - -	15
Gault and Rock at bottom - - - - -	110
	125

78. Whaddon. Well at Mr. F. J. Carver's house.
Communicated by R. Piggott (well-sinker).
Water overflows.

	Feet.
[Chalk Marl] to coprolites - - - - -	17
Gault clay - - - - - - - -	171
[Lower Greensand] rock and sand, punched - -	10
	198

79. WHADDON. West of Church, and in front of the Inn.
Water overflows.
Clunch and Gault, said to be 200 or 300 feet.

80. WICKEN. (51 N.W.)
Communicated by Mr. Flavell.

	Feet.
Soil	3
Blue clay	10
Black rock	1
Blue clay	2
Black rock	1
Blue clay	5
Similar alternations for	178
	200

81. WIMPOLE. Coprolite Works.

	Feet.
[Gault] blue clay	175
[Lower Greensand] rock and sands, varies—about	12
	187

82. WIMPOLE. Coprolite Works, near The Ruins.
Sunk 120 feet, the rest bored.
Water, 80 feet from surface.

	Feet.
Clunch and Gault	180

HERTFORDSHIRE.

83. GUILDEN MORDEN. Coprolite Works W. of. (46 N.E.)
Communicated by H. G. Fordham, Esq.
Sunk 52 feet, the rest bored.

	Feet.
Chalk Marl, with coprolites at bottom	20
Gault, with bed of coprolites a few feet from the bottom	172
	192

HUNTINGDONSHIRE.

84. BLUNTISHAM. Mr. Tebbuts. (51 N.W.)
Very little water; drains in from hard beds.

	Feet.
Oxford clay, with hard bands	300

APPENDIX D.—BORINGS.

CAMBRIDGESHIRE.

CHESTERTON. N.E. of the Ferry. Trial boring.

From a MS. book of sections in the Office of the Geological Survey, Jermyn Street, London:

		Feet.
Made ground		4
Black peat		2
[Valley Drift]	Hard gravel	2
	White gravel	4
	Shingly gravel	4
[Gault]* blue clay		5
		21

RAMPTON. Side of road to Willingham, probably near the Church. Trial boring. (51 N.W.)

From a MS. book of sections in the Office of the Geological Survey, Jermyn Street, London.

		Feet.
Oxford Clay †	Solid brown clay, with a white stone	4
	White rock and gravel, very hard	2
	Coloured clay	2
	Blue clay, streaked with white and small spots of talc [selenite]	3
		11

WILLINGHAM and BLUNTISHAM. (51 N.W.)

From a MS. book of sections in the Office of the Geological Survey, Jermyn Street, London.

No. 3.—By the side of the River Ouse [probably by the Hermitage].

	Feet.
Brick earth	2
Black bog	5
Black peat, rather stiff	2
Shingly gravel, with sand	11
Blue [Oxford] clay	to 1½
	21½

No. 4.—North of the above between the "Old and New Bedford Levels" (*i.e.*, between "The Washes").

	Feet.
Clay	2½
Sand and clay	7½
Gravel and sand	2
Blue [Oxford] clay	4
	16

* Wrongly marked as Kimeridge Clay in the Memoir on the Geology of the Fenland, p. 254.

† Wrongly marked as Boulder Clay in the Memoir on the Geology of the Fenland, p. 146.

No. 4*a*.—Earith Wash. Further N. or N.E. in similar situation.

	Feet.
Yellow clay	5
Black peat	18
Loam and sand	2
Loam and flint	2
Gravel, sand, and stone	3
Blue [Oxford] clay	1
	31

No. 4*b*.—Still further N.E., in similar situation.

	Feet.
Yellow clay	$2\frac{1}{2}$
Black peat	$3\frac{1}{2}$
Light yellow clay	3
Coloured clay	1
Light sand and clay	2
Clean sand	1
Gravel and sand	2
Blue [Oxford] clay	3
	18

HUNTINGDONSHIRE.

EARITH. St. Ives Extension Railway. (51 N.W.)

Communicated by Mr. A. Johnston, Resident Engineer.

Distance from Sutton.		Feet.
4 miles 53 chains	Near the Old West River:	
	"Bear's muck" and rotten peat	15
	Silt and gravel	3
	Gravel	12
	Oxford clay	—
4 „ 69 „	Near engine-drain:	
	"Bear's muck" and rotten peat	11
	Silt, with a few stones	5
	Hard gravel	9
	Oxford clay	—
5 „ 20 „	Peat and "bear's muck"	10
	Silt and gravel	3
	Hard gravel	—
5 „ 45 „	Peat and "bear's muck"	8
	Buttery clay	4
	Gravel	13
	Oxford clay	—
5 „ 75 „	Peat and "bear's muck"	10
	Buttery clay	8
	Silt and gravel	3
	Hard gravel	—

APPENDIX E.

LIST OF WORKS ON THE GEOLOGY OF CAMBRIDGESHIRE. Compiled by W. WHITAKER.

I. GEOLOGICAL SURVEY PUBLICATIONS.

Maps.

Sheet 46, N.E. (small part). By W. WHITAKER and F. J. BENNETT. 1869.
Sheet 52, N.E. (small part). By H. H. HOWELL. 1864.
Sheet 64 (part). By J. W. JUDD. 1872.
Sheet 47 (part). By W. H. PENNING. 1881.

Memoirs.

Decade XII. (Plates 9 and 10. Fish from the Kimeridge Clay, Cottenham). By PROF. T. H. HUXLEY. 1866.
The Geology of the London Basin. Part I. The Chalk and the Eocene Beds of the Southern and Western Tracts (p. 45). By W. WHITAKER. 1872.
The Geology of Rutland and the Parts of . . . . Cambridge included in Sheet 64 of the 1-inch Map of the Geological Survey . . . . By J. W. JUDD. 1875.
The Geology of the Fenland. By S. B. J. SKERTCHLY. 1877.
The Geology of the N.W. part of Essex and the N.E. part of Herts, with parts of Cambridgeshire and Suffolk. (Explanation of Sheet 47.) 1878.
A Catalogue of the Cretaceous Fossils in the Museum of Practical Geology. 1878.

Monograph IV. The Chimæroid Fishes of the British Cretaceous Rocks. By E. T. NEWTON (pls. i., ii., vi–x., xii.). 1878.

2. CHRONOLOGICAL LIST OF BOOKS, PAPERS, &c.

Reprinted, with Additions and Corrections, from a List (by W. W.) printed for the Woodwardian Museum in 1873. I have to thank my colleague, Mr. W. H. DALTON, for his assistance in bringing this up to date.

The many works relating merely to the drainage of the Fens have not been included, but their titles may be found in the list in Mr. SKERTCHLY'S Memoir on the Geology of the Fenland (see above).

INDEX OF AUTHORS, with the Numbers affixed to their Papers, &c. in the List.

1794.

1. VANCOUVER, C. - General View of the Agriculture in the County of Cambridge. (Map of Soils. Appendix on the Fens, with Borings.) 4to. London.

1814.

2. WARBURTON, H. - A Description of some Specimens from the neighbourhood of Cambridge. (*Geol. Soc.*) *Ann. of Phil.*, vol. iii. p. 72.

1815.

3. HAILSTONE, REV. PROF. J. - - Supplementary Communication on Cambridge. (*Geol. Soc.*) *Ann. of Phil.*, vol. v. p. 390. [? included in No. 5.]

4. SOWERBY, J. - - The Mineral Conchology of Great Britain, vol. i. (p. 201). 8vo. Lond.

1816.

5. HAILSTONE, REV. PROF. J. - - *Trans. Geol. Soc.*, vol. iii. p. 243. Outlines of the Geology of Cambridgeshire.

1819.

6. ANON. - - - - Organic Remains (Antlers, Brink). *Quart. Journ. of Lit. Sci. and Arts*, vol. vii. p. 192.

7. LUNN, F. - - - On the Strata of the Northern Division of Cambridgeshire. *Trans. Geol. Soc.*, vol. v., p. 114.

8. SMITH, W. - - Geological View and Section of the Country between London and Cambridge.

9. ——— - - Geological View and Section through Suffolk to Ely.

1821.

10. OKES, J. - - - An Account of some Fossil remains of the Beaver, found in Cambridgeshire. *Trans. Camb. Phil. Soc.*, vol. i. p. 175.

1822.

11. THACKERAY, F. - On a remarkable instance of Fossil Organic Remains found near Streatham in the Isle of Ely. *Trans. Camb. Phil. Soc.*, vol. i. part ii. p. 459.

1824, 1825.

12. SOWERBY, J. - - The Mineral Conchology of Great Britain, vol. v. (Cambridgeshire, pp. 5, 6, 53, 54). 8vo. London.

1825.

13. SEDGWICK, REV. PROF. A. On the Origin of Alluvial and Diluvial Formations (Cambridge, pp. 244, 251, and 22). *Ann. of Phil.*, Ser. 2, vol. ix. p. 241, and vol. x. p. 18.

1827.

14. WATSON, W. - - Historical Account of Wisbeach (Notices of Bones, pp. 58, 578, &c.).

1836.

15. ANON. - - - A Notice of the Occurrence of certain Bodies in the Greensand at Cambridge, that are similar to those found in the Gault at Folkstone . . . . and some Information on the Greensand and contiguous Strata at Cambridge. *Mag. Nat. Hist.*, vol. ix. p. 264.

16. FITTON, DR. W. H. - Observations on some of the Strata between the Chalk and the Oxford Oolite, in the South-east of England. *Trans. Geol. Soc.*, Ser. 2, vol. iv. p. 100. Abstract, under a different title, in *Proc. Geol. Soc.*, vol. i. p. 26 (1827).

1838.

17. MITCHELL, DR. J. - On the Drift from the Chalk and the Strata below the Chalk in the counties of Norfolk, Suffolk, Essex, Cambridge, &c. *Proc. Geol. Soc.*, vol. iii. p. 3.

1840.

18. OWEN, [PROF.] R. - Report on British Fossil Reptiles (Cambridgeshire, pp. 74, 75). *Rep. Brit. Assoc.* for 1839, p. 43.

1842.

19. OWEN, PROF. R. - Report on British Fossil Reptiles. (Part 2, Cambridge, p. 172.) *Rep. Brit. Assoc.* for 1841, p. 60.

1843.

20. FISHER, M. - - Note on the Occurrence of the Bones of a Beaver, &c., near Ely. *Zoologist*, vol. i. p. 348.

21. OWEN, PROF. R. - Report on the British Fossil Mammalia. (Cambridge, pp. 64, 69.) *Rep. Brit Assoc.* for 1842, p. 54.

1844.

22. BRODIE, REV. P. B. - Notice on the Occurrence of Land and Freshwater Shells with Bones of some extinct Animals in the Gravel near Cambridge. With Notes by the Rev. Prof. SEDGWICK. *Trans. Cambridge Phil. Soc.*, vol. viii. part 1, p. 138

1846.

23. Carter, J. - - On the Occurrence of a new species of Ichthyosaurus in the Chalk (Cambridge).—(British Assoc.) *London Geol. Journ.*, p. 7.

24. Henslow, Rev. Prof. On Nodules, apparently Coprolitic, from the Red Crag, London Clay, and Green Sand. *Rep. Brit. Assoc.* for 1845, *Trans. of Sections*, p. 51.

25. Jenyns, Rev. L. - On the Turf of the Cambridgeshire Fens. *Ibid.*, p. 75.

26. Owen, Prof. R. - A History of British Fossil Mammals and Birds. 8vo. Lond.

27. Sedgwick, Rev. Prof. A. On the Geology of the Neighbourhood of Cambridge, including the Formations between the Chalk Escarpment and the Great Bedford Level. *Rep. Brit. Assoc.* for 1845, *Trans. of Sections*, p. 40.

1847.

28. Davidson, T., and Prof. J. Morris. Description of some species of Brachiopoda (Cambridge, p. 254). *Ann. and Mag. Nat. Hist.*, vol. xx. p. 250.

29. Jonas, S. - - - On the Farming of Cambridgeshire (Remarks on the Geology, with Sections). *Journ. Roy. Agric. Soc.*, vol. vii. p. 35.

1848.

30. M'Coy, [Prof.] F. - On some new Mesozoic Radiata. *Ann. and Mag. Nat. Hist.*, Ser. 2, vol. ii. p. 397.

1849.

31. M'Coy, [Prof.] F. - On the Classification of some British Fossil Crustacea, &c. (Cambridge, p. 332). *Ann. and Mag. Nat. Hist.*, Ser. 2, vol. iv. p. 330.

32. Walker, N., and T. Craddock. The History of Wisbech and the Fens. Chap. i., "Physical Characteristics." Appendix, "Sketch "of the Geology of the Fens," by H. M. Lee, pp. 541–3. 8vo. Wisbech.

1850.

33. Hamilton, W. J. - On the Occurrence of a Freshwater Bed of Marl in the Fens of Cambridgeshire. *Quart. Journ. Geol. Soc.*, vol. vi. p. 451.

34. Milne-Edwards, Prof. A., and J. Haime. A Monograph of the British Fossil Corals. Part 1. (Cambridge, pp. 63, &c.). *Palæontograph. Soc.*

1851.

35. Owen, Prof. R. - Monograph on the Fossil Reptilia of the Cretaceous Formations (Cambridge, pp. 8, 19, 55, 64, 72, &c.). *Palæontograph. Soc.*

36. Prestwich, J. - A Geological Inquiry respecting the Water-bearing Strata of the Country around London, &c. 8vo. Lond. (Cambridge, pp. 76, 90, 144, 146.)

1852.

37. Davidson, T. - - A Monograph of British Cretaceous Brachiopoda. (Cambridge, p. 42.) *Palæontograph. Soc.*

1854.

38. M'Coy, Prof. F. - On some new Cretaceous Crustacea. (Cambridge, pp. 118, 120, 122.) *Ann. and Mag. Nat. Hist.*, Ser. 2 vol. xiv. p. 116.

39. TRIMMER, J. - - On some Mammaliferous Deposits in the Valley of the Nene, near Peterborough. *Quart. Journ. Geol. Soc.*, vol. x. p. 343.

1855.

40. SHARPE, D. - - Description of the Fossil Remains of Mollusca found in the Chalk of England. Part 2. Cephalopoda (Cambridge, p. 29). *Palæontograph. Soc.*

1856.

41. FORBES, PROF. E., and J. W. SALTER. Decade 5 (Plate 5. Fossils from Cambridge Chalk). *Geological Survey Memoirs*, 4to. and 8vo. Lond.

1857.

22. JONES [PROF.] T. R. - A Monograph of the Tertiary Entomostraca of England. (Cambridge, pp. 12, 14, &c.) *Palæontograph. Soc.*

43. SPENCE. - - - [On Coprolites.] *Proc. Lit. and Phil. Soc. Manchester*, vol. i., No. 1, p. 3.

1859.

44. BARRETT, L. - - Geological Map of the Neighbourhood of Cambridge (Drawn and Coloured on the Ordnance Sheet, 51 S.W.)

45. OWEN, PROF. R. - On remains of New and Gigantic Species of Pterodactyle (P. Fittoni and P. Sedgwicki) from the Upper Greensand near Cambridge. *Rep. Brit. Assoc.* for 1858, *Trans. of Sections*, p. 98.

46. ———— - On the Vertebral Characters of the Order Pterosauria, as exemplified in the Genera Pterodactylus and Dimorphon. *Phil. Trans.*, vol. cxlix. (part. i.) p. 161.

47. ———— - Monograph on the Fossil Reptilia of the Cretaceous Formations. Supplement No. 1. Pterosauria (Pterodactylus). *Palæontograph. Soc.*

48. ROSE, C. B. - - Geological Pearls (Ely, Cherry Hinton). *Geologist*, vol. ii. p. 295.

49. WRIGHT, DR. T. - A Monograph on the British Fossil Echinodermata from the Oolitic Formations. Part Third. (Cambridge, p. 318.) *Palæontograph. Soc.*

1860.

50. VOELCKER, DR. A. - On the Chemical Composition and Commercial value of......Coprolites and other Phosphatic Materials used in England for Agricultural Purposes. (Analyses of Cambridge "Coprolites," pp. 357, 358.) *Journ. Roy. Agric. Soc.*, vol. xxi. p. 350.

51. WELLS, W. - - The Drainage of Whittlesea Mere (Analyses of Clays, &c., p. 148). *Ibid.* p. 134.

1861.

52. DENNIS, REV. J. B. P. On the Mode of Flight of the Pterodactyles of the Coprolite Bed near Cambridge. *Rep. Brit. Assoc.* for 1860, *Trans. of Sections*, p. 76.

53. OWEN, PROF. R. - Monograph of the Fossil Reptilia of the Cretaceous and Purbeck Strata (Supplement). *Palæontograph. Soc.*

54. PORTER, DR. H. - The Geology of Peterborough and its Neighbourhood. 8vo. Peterborough.

55. SEDGWICK, REV. PROF. A. - - A Lecture on the Strata near Cambridge and the Fens of the Bedford Level. 8vo. Privately printed.

56. SEELEY, H. G. - - Notes on Cambridge Palæontology. No. 1. Some new Upper Greensand Bivalves. No. 2. Some new Gasteropods from the Upper Greensand. No. 3. On a new Order of Echinoderms. No. 4. Some new Upper Greensand Echinoderms. *Ann. and Mag. Nat. Hist.*, Ser. 3, vol. vii. pp. 116, 281, 365, and vol. viii. p. 16.

57. ———— - - On Some Anomalous Fossils from the Upper Greensand of Cambridge. *Proc. Geol. Assoc.*, vol. i. p. 147.

1862.

58. ANON. - - - Turtle Remains in the Upper Greensand. *Geologist*, vol. v. p. 73.

59. SEELEY, H. G. - - Notes on Cambridge Geology.—1. Preliminary Notice of the Elsworth Rock and associated Strata (Brit. Assoc.). *Ann. and Mag. Nat. Hist.*, Ser. 3, vol. x. p. 97.

1863.

60. BELL, PROF. - - A Monograph of the Fossil Malacostracous Crustacea of Great Britain. Part ii. Crustacea of the Gault and Greensand. (Cambridge, pp. 4, &c.) *Palæontograph. Soc.*

61. PORTER, DR. H. - On the Occurrence of large Quantities of Fossil Wood in the Oxford Clay near Peterborough. *Quart. Journ. Geol. Soc.*, vol. xix. p. 317.

62. SEELEY, H. G. - - On a Whittled Bone from the Barnwell Gravel. *Rep. Brit. Assoc.* for 1862, *Trans. of Sections*, p. 94.

1864.

63. OWEN, PROF. R. - Monograph of the Fossil Reptilia of the Cretaceous and Purbeck Strata (Supplement). *Palæontograph. Soc.*

64. ROSE, C. B., and W. DAVIES. [Letters] on the occurrence of Cycloid Fish-scales, &c.,...in the Oolitic Formation. *Geol. Mag.*, vol. i. p. 92.

65. SEELEY, H. G. - A Monograph of the Ammonites of the Cambridge Greensand—(Abstract.—included in No. 71.) *Quart. Journ. Geol. Soc.*, vol. xx. p. 166.

66. ———— Mytilus spathulatus, a new Cretaceous Species. *Geologist*, vol. vii. p. 53.

67. ———— On a section of the Lower Chalk near Ely. *Geol. Mag.*, vol. i. p. 150.

68. WOODWARD, S. P. - Note on Plicatula sigillina, an undescribed Fossil of the Upper Chalk and Cambridge Phosphate Bed. *Geol. Mag.*, vol. i. p. 112.

69. WRIGHT, DR. T. - A Monograph of the Fossil Echinodermata from the Cretaceous Formations. (Cambridge, p. 39.) *Palæontograph. Soc.*

1865.

70. SEELEY, H. G. - On a new Lizard with Ophidian Affinities from the Lower Chalk. (Saurospondylus dissimilis.) *Ann. and Mag. Nat. Hist.*, Ser. 3, vol. xvi. p. 105.

71. ———— On Ammonites from the Cambridge Greensand. *Ibid*, p. 225.

72. ———— On the Fossil Neck-bones of a Whale from the neighbourhood of Ely. *Geol. Mag.*, vol. ii. p. 54.

73. ———— On the significance of the sequence of Rocks and Fossils. Theoretical considerations of the Upper Secondary Rocks, as seen in the section at Ely. *Ibid.*, p. 262.

74. SEELEY, H. G. - On a section discovering the Cretaceous Beds at Ely. *Ibid.*, p. 529.

75. WOOD, S. V., JUNR. - A Map of the Upper Tertiaries in the Counties of Norfolk, Suffolk, Essex, Middlesex, Hertford, Cambridge, &c. (With remarks and sections.) Privately printed.

1866.

76. FISHER, REV. O. - On the warp (of Mr. Trimmer), its age, and probable connexion with the last Geological Events *Quart. Journ. Geol. Soc.*, vol. xxii. p. 553.

77. SEELEY, H. G. - A sketch of the Gravels and Drift of Fenland. *Quart. Journ. Geol. Soc.*, vol. xxii. p. 470.

78. ———————— The Rock of the Cambridge Greensand. *Geol. Mag.*, vol. iii. p. 302.

79. ———————— Theoretical remarks on the Gravel and Drift of the Fenlands. *Ibid.*, p. 495.

1867.

80. FISHER, REV. O. - On Roslyn or Roswell Hill Clay-pit, near Ely. *Proc. Cambridge Phil. Soc.*, Part iv., p. 51, and *Geol. Mag.*, vol. v. pp. 407, 438 (1868).

81. JENYNS, REV. L. - A lecture on the Phosphatic Nodules obtained in the Eastern Counties, and used in Agriculture. *Proc. Bath. Nat. Hist. and Antiq. Field Club*, vol. i., No. 1. p. 9.

82. MOORE, N. - - Megaceros Hibernicus in the Cambridgeshire Fens. *Ann. and Mag. Nat. Hist.*, Ser. 3., vol. xx. pp. 77, 301. See also SEELEY, p. 152.

83. SEELEY, H. G. - On the Association of Potton Sand Fossils with those of the Farringdon Gravels in a phosphatic deposit at Upware on the Cam; with an account of the superposition of the beds, and the significance of the Affinities of the Fossils. *Proc. Camb. Phil. Soc.*, Parts v., vi., p. 99.

84. WALKER, J. F. - On some new Coprolite Workings in the Fens. *Geol. Mag.*, vol. iv. p. 309.

85. ———————— On some new Terebratulidæ from Upware. *Ibid.*, p. 454.

86. WOOD, S. V., JUNR. - On the structure of the Post-glacial Deposits of the south-east of England. *Quart. Journ. Geol. Soc.*, vol. xxiii. p. 394. (Corrections in *Geol. Mag.*, vol. v. pp. 43, 534.)

1868.

87. KEEPING, H. - - Discovery of Gault with Phosphatic Stratum at Upware. *Geol. Mag.*, vol. v. p. 272.

88. MILNE-EDWARDS, A. Note on the existence of a large Pelican in the Turbaries of England. (Translated from *Comptes Rendus*, p. 1242.) *Ann. and Mag. Nat. Hist.*, Ser. 4, vol. ii. p. 165.

89. SEELEY, H. G. - On the Collocation of the Strata at Roswell Hole near Ely. *Geol. Mag.*, vol. v. p. 347.

90. WALKER, J. F. - On a new Phosphatic Deposit, near Upware, Cambridgeshire. *Rep. Brit. Assoc.* for 1867, *Trans. of Sections*, p. 73.

91. ———————— - On the Species of Brachiopoda which occur in the Lower Greensand at Upware. *Geol. Mag.*, vol. v. p. 399.

92. ———————— - - Occurrence of Terebratula (Waldheimia) pseudo-jurensis (Leymerie) in England [at Upware]. *Ann. and Mag. Nat. Hist.*, Ser. 4, vol. i. p. 386.

93. ———————— - - On the Occurrence of the genus Anser in the Peat and Gravel Deposits in Cambridgeshire. *Ibid.*, vol. ii. p. 388.

1869.

94. DAVIDSON, T. - - Notes on Continental Geology and Palæontology. [Remarks on the Cambridge Greensand, with a letter from J. F. WALKER.] *Geol. Mag.*, vol. vi. p. 259.

95. DUNCAN, [PROF.] P. M. First report on the British Fossil Corals (Cambridge, pp. 95, 96). *Rep. Brit. Assoc.* for 1868, p. 75.

96. ——————— A Monograph of the British Fossil Corals. Second Series (Cretaceous). (Cambridge, pp. 19, 20.) *Palæontograph. Soc.*

97. SEELEY, H. G. - - Discovery of Dakosaurus in England. *Geol. Mag.*, vol. vi. p. 188.

98. ——————— - - Index to the Fossil Remains of Aves, Ornithosauria, and Reptilia from the Secondary System of Strata, arranged in the Woodwardian Museum of the University of Cambridge. With a Prefatory Note by the REV. PROF. A. SEDGWICK. 8vo. Cambridge and London.

1870.

99. CARPENTER, DR. W. B., and H. B. BRADY. Description of Parkeria and Loftusia, two gigantic types of Arenaceous Foraminifera. *Phil. Trans.*, vol. clix. (part 2), p. 721.

100. LANKESTER, E. R. - On a new Large Terebratula occurring in East Anglia. *Geol. Mag.*, vol. vii. p. 410.

101. PHILLIPS, PROF. J. A Monograph of British Belemnitidæ. Part v., containing pp. 109–128; Plates xxviii., xxxvi. (St. Ives, Pl. xxviii.)

102. SEELEY, H. G. - The Ornithosauria: an Elementary Study of the Bones of Pterodactyles, made from Fossil Remains found in the Cambridge Upper Greensand. 8vo. Cambridge and Lond.

103. ——————— - - On the Frontal Bone in the Ornithosauria; with additional evidence of the structure of the land in Pterodactyles from the Cambridge Upper Green Sand. *Proc. Camb. Phil. Soc.*, No. xi., p. 186 (8 lines.)

104. WALKER, J. F. - On Secondary Species of Brachiopoda. *Ibid.*, p. 560.

105. WOODWARD, H. - Contributions to British Fossil Crustacea. *Ibid.* p. 493 (Error, p. 588).

1871.

106. FISHER, REV. O. - On supposed Thermal Springs in Cambridgeshire [Letter]. *Geol. Mag.*, vol. viii. p. 42.

107. ——————— - On Phenomena connected with Denudation, observed in the so-called Coprolite Pits near Haslingfield, Cambridgeshire. *Ibid.*, p. 65, and *Proc. Camb. Phil. Soc.*, Part xii., pp. 195, 196.

108. HARMER, F. W. - On some Thermal Springs in the Fens of Cambridgeshire. *Rep. Brit. Assoc.* for 1870, *Trans. of Sections*, p. 74.

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Plate I

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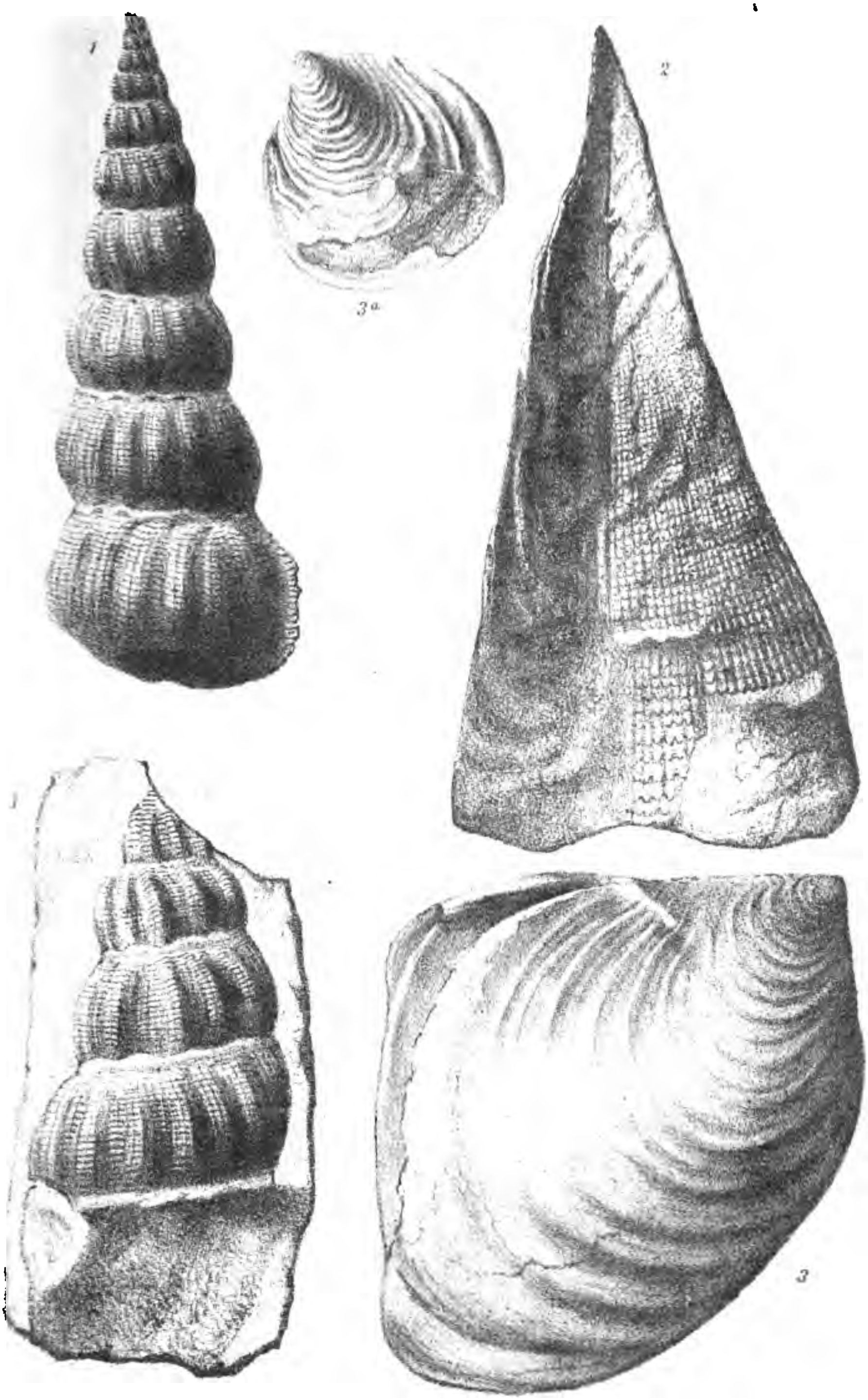

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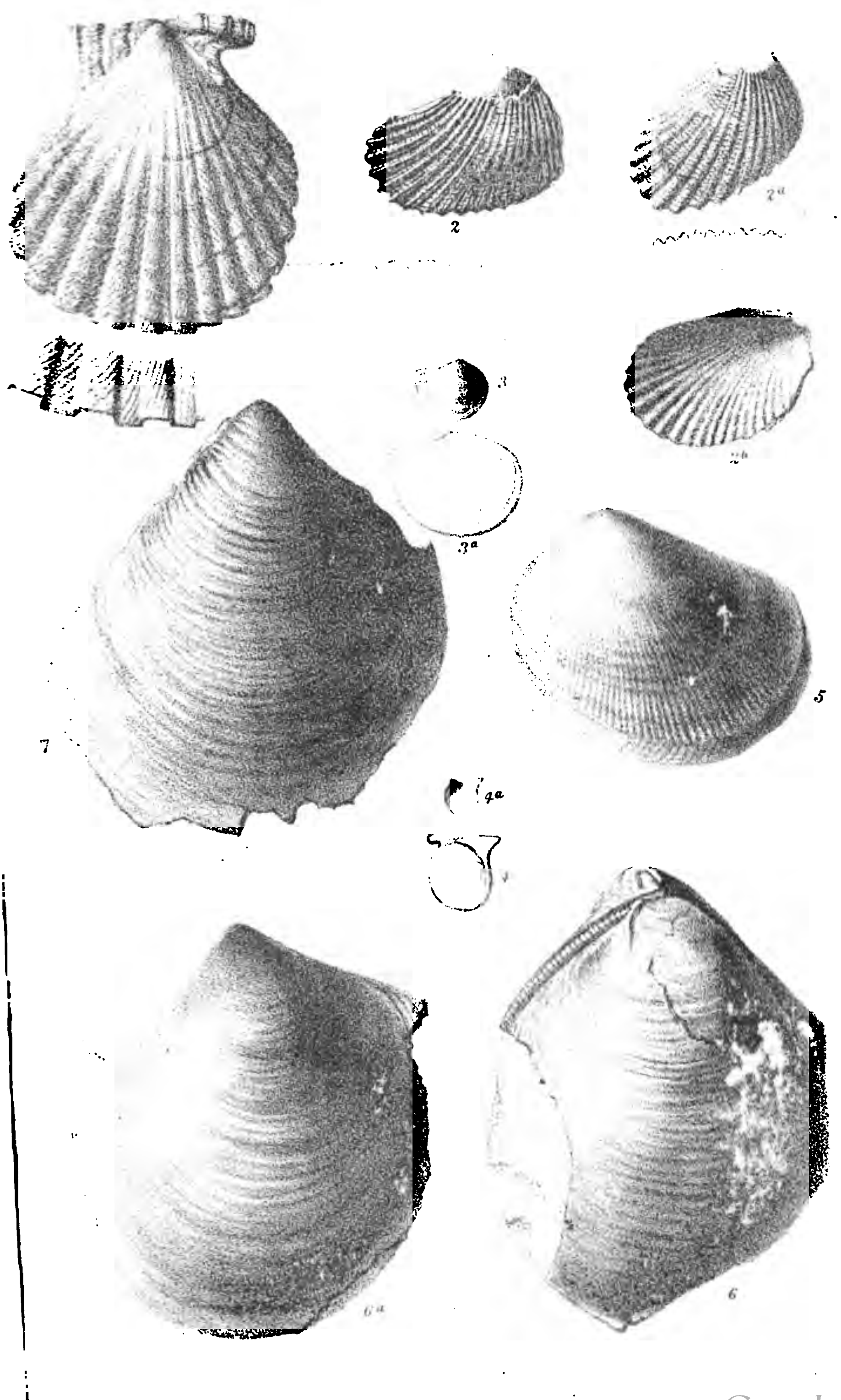
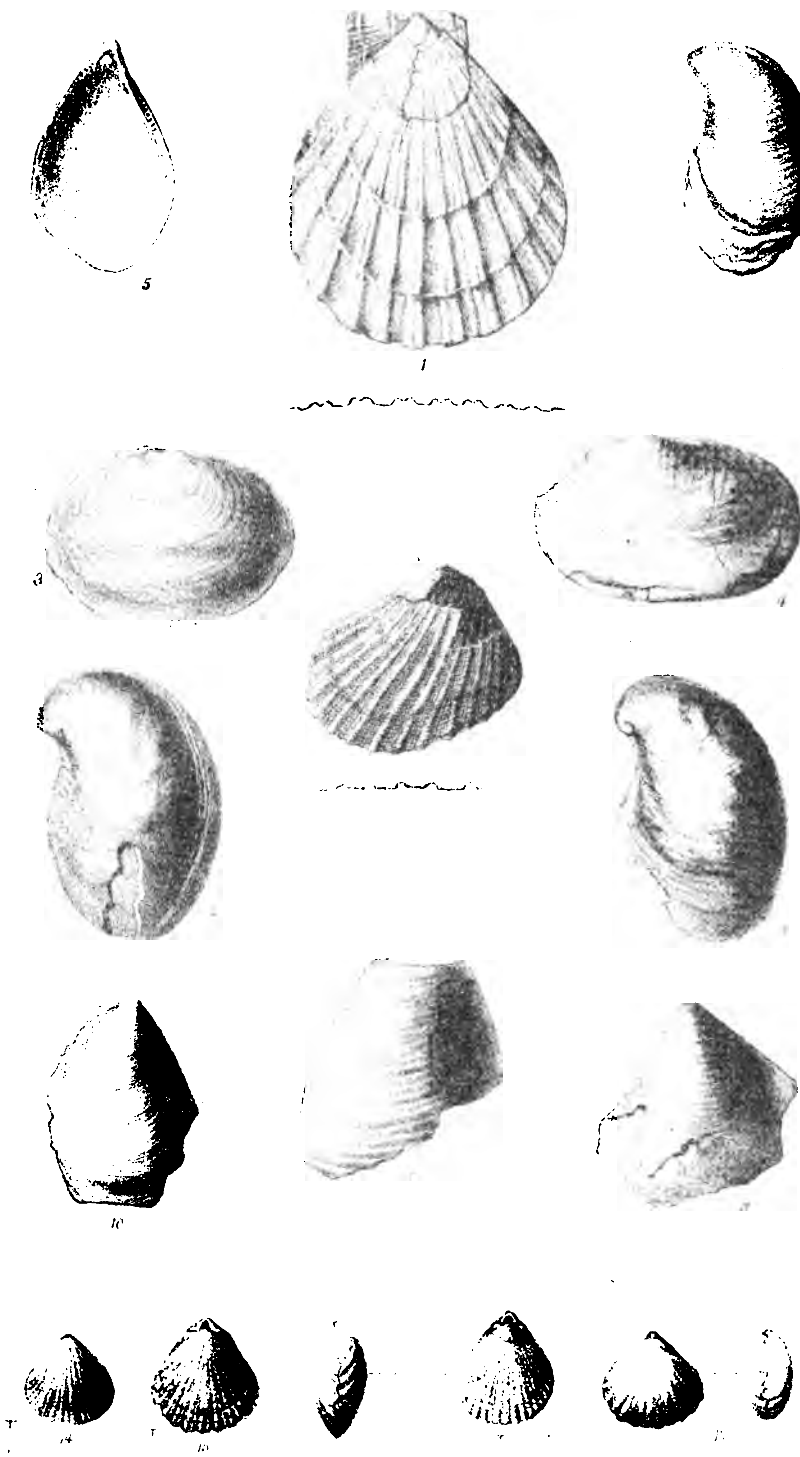
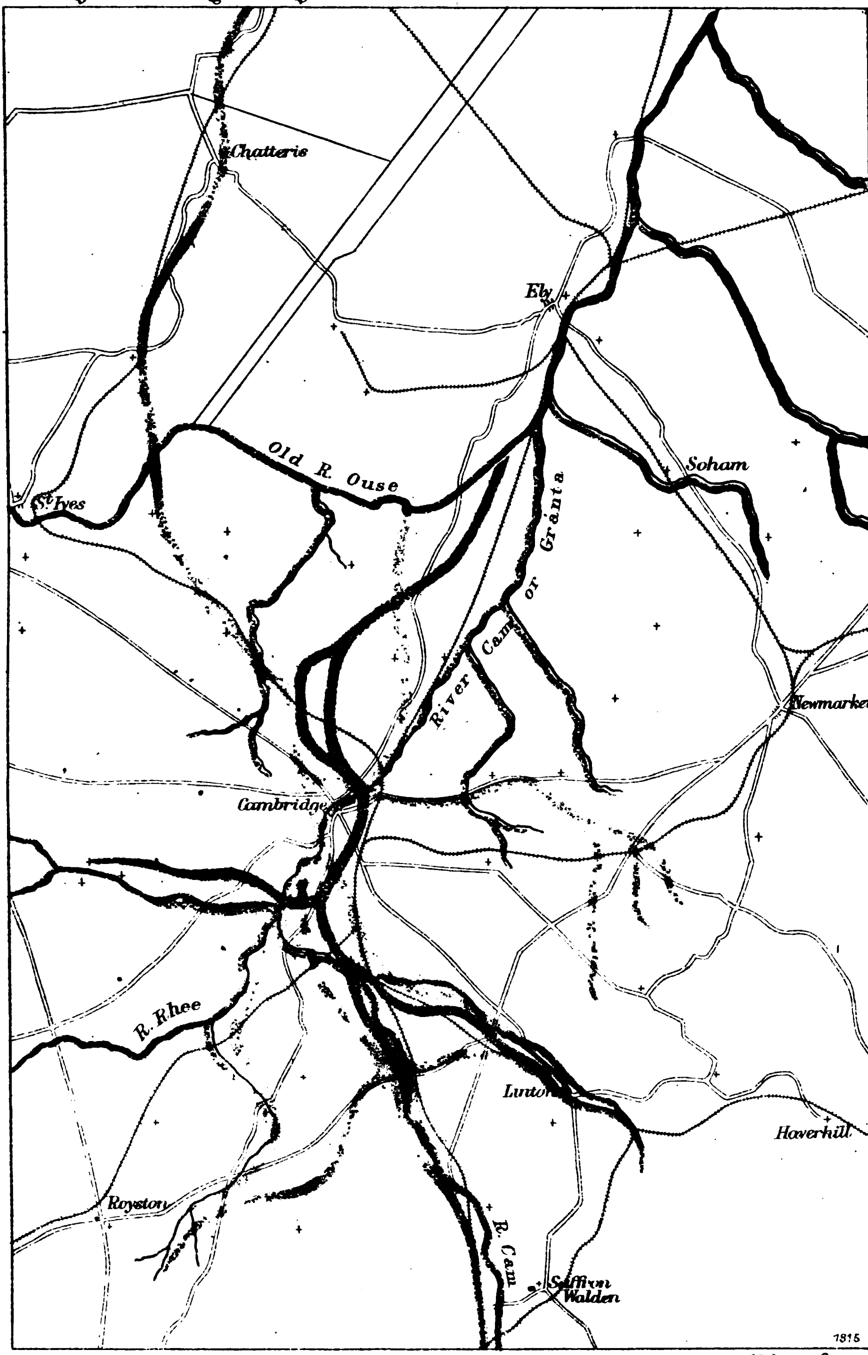


Plate III

GEOLOGICAL SURVEY OF ENGLAND AND WALES



Geological Survey of England & Wales   Plate 4.



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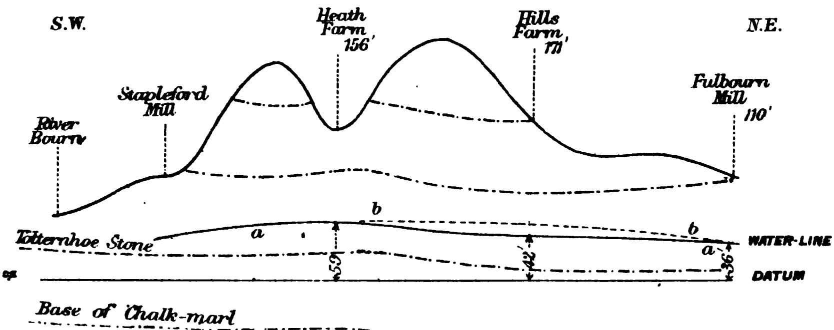
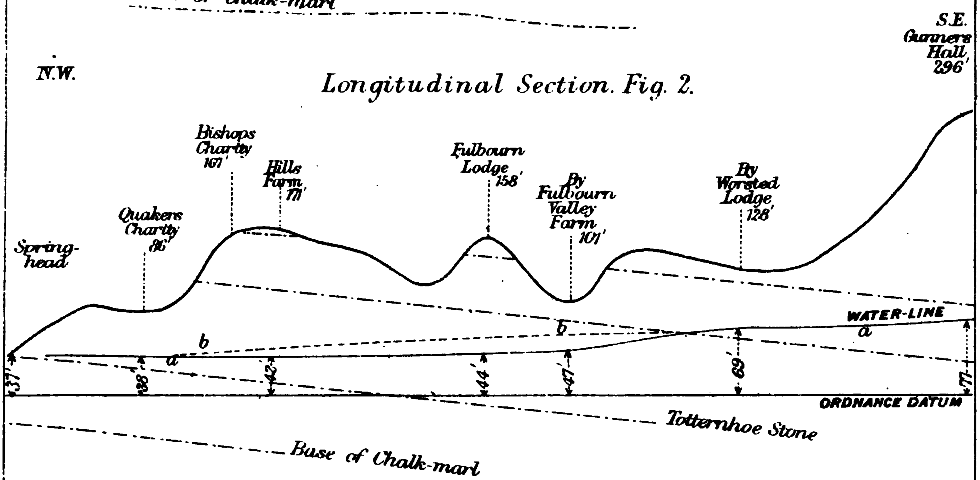


Longitudinal Section. Fig. 2.



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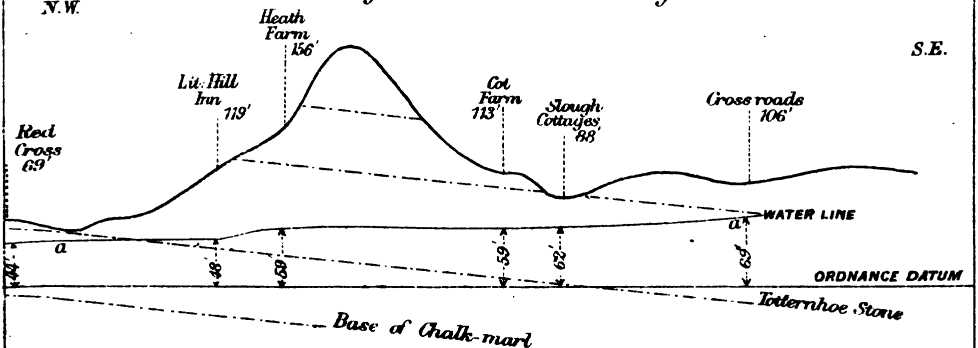

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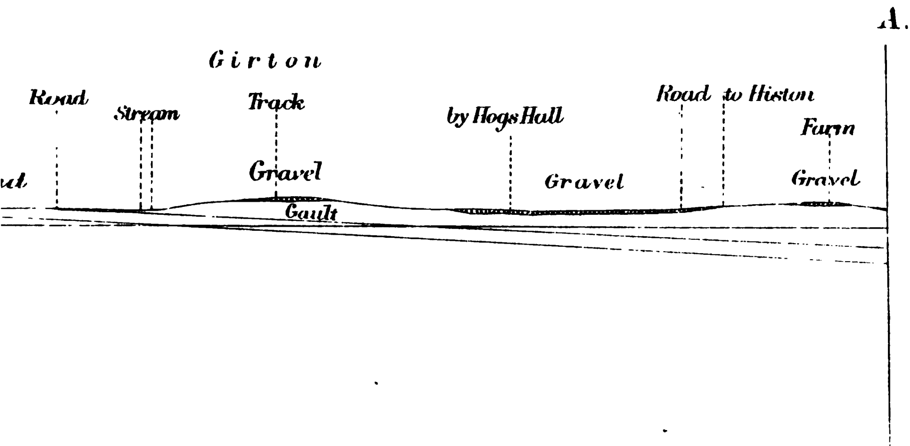

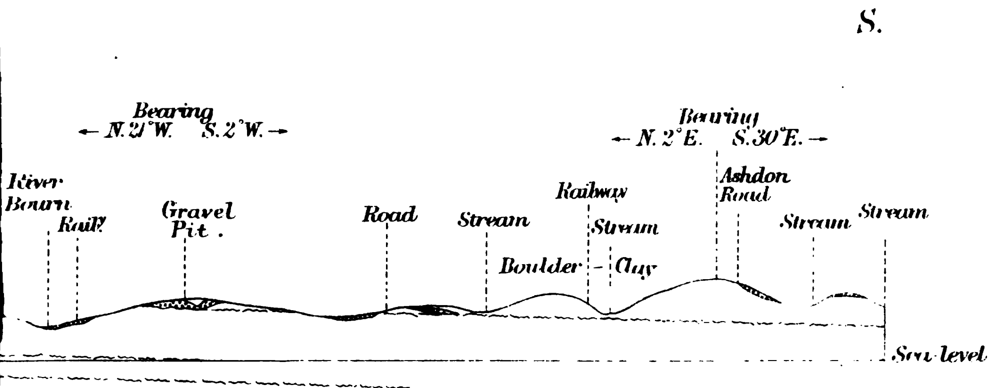

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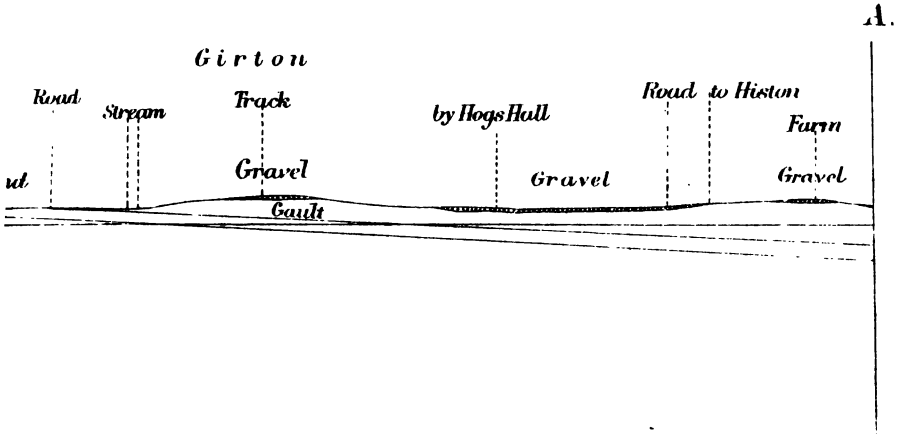
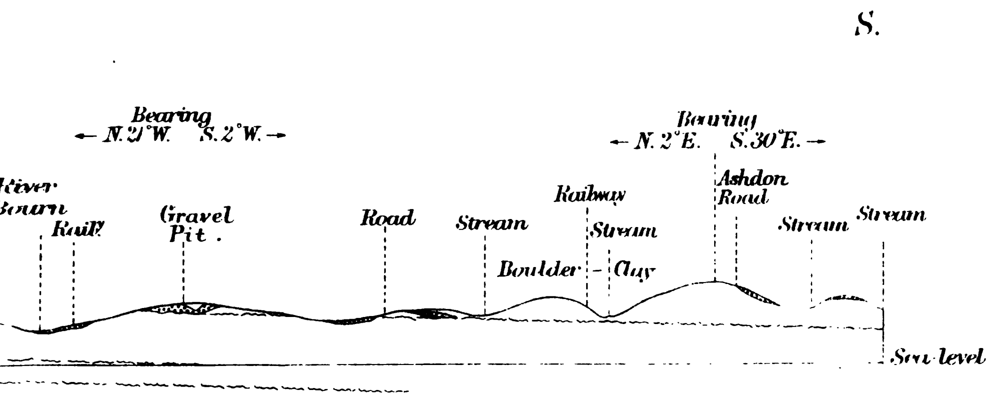
Feet

Geology of the Neighbourhood of Cambridge. Plate 6.





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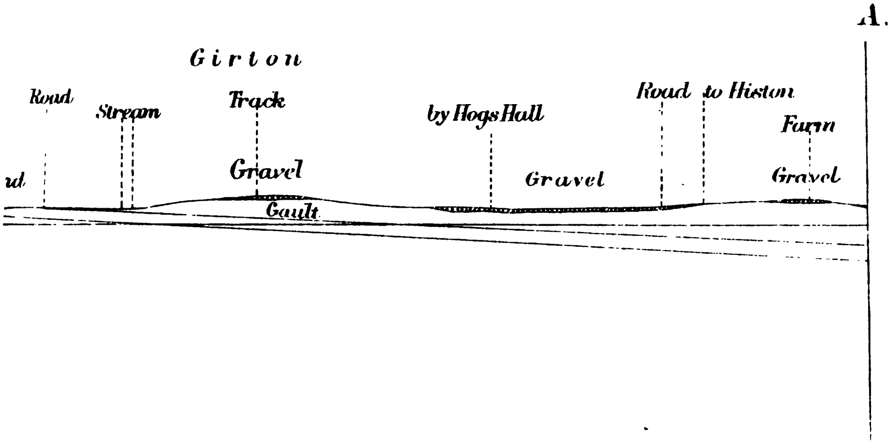

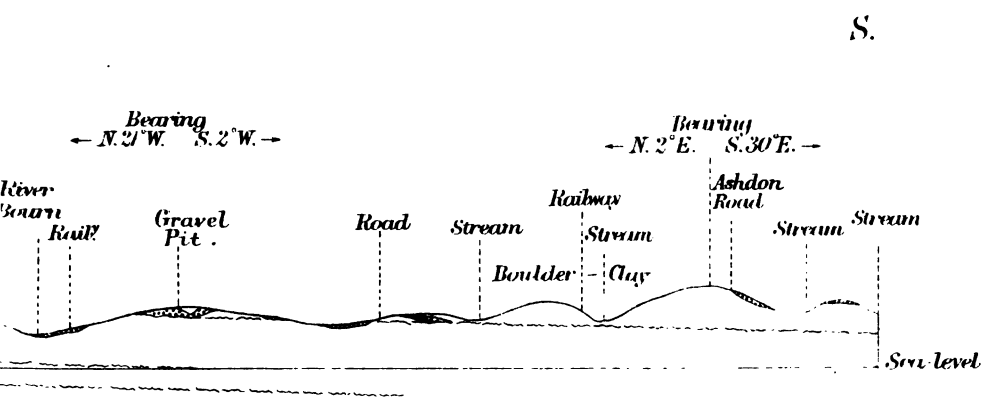

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